ONTARIO POWER GENERATION

Report

Public Information	
Document Number: N-REP-03481-10010	
Sheet Number: N/A	Revision: R000

Title:
2011 RESULTS OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAMS

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2011 Results of Radiological Environmental Monitoring Programs

N-REP-03481-10010-R000
2012-04-16

Order Number: N/A
Other Reference Number: N/A

Public Information

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Acknowledgement

Ontario Power Generation, Nuclear, would like to thank the residents of the local communities in the vicinity of Pickering and Darlington stations, and throughout the Province of Ontario who have voluntarily participated in our environmental monitoring programs. Their support in allowing OPG to have environmental monitoring stations on their properties and supplying samples of vegetables, fruits, honey, soil, silage, milk and water have helped ensure that the annual public dose estimates are realistic.

Revision Summary

Revision Number	Date	Comments
R000	2012-04-16	Initial issue. This document contains 61 physical pages.

Executive Summary

Ontario Power Generation (OPG) conducts Radiological Environmental Monitoring Programs (REMPs) in the vicinity of Darlington Nuclear (DN) and Pickering Nuclear (PN) stations to determine the radiological impact on the public resulting from the operation of these stations. This annual report is a requirement of the station operating licenses. It contains the 2011 results of the monitoring programs, which include concentrations of radionuclides in the air, water, milk, soil, sediments, vegetation and fish samples taken in the vicinity of DN and PN, and the associated radiation dose assessments. Samples at provincial locations were also taken to determine background radiation levels in areas away from the influence of nuclear stations.

No significant changes were made to the REMPs in 2011. A total of 2,350 laboratory analyses were performed on a variety of environmental media in 2011. The availabilities of samples analyzed for the dose calculation were above the minimum annual performance requirements.

IMPACT 5.4.0 software, which represents the method of dose calculation described in the CSA N288.1-08 standard [R-11], was used for the dose calculation.

The 2011 radiation dose assessments for DN and PN demonstrate that the critical group doses resulting from the operation of the OPG Nuclear Generating Stations continue to be a very small fraction of both the annual legal limit of 1,000 microsieverts (μSv) and the estimated annual average background radiation dose around DN and PN of 1,400 μSv. The official public doses for the DN and PN sites are summarized in Table 1 and described as follows:

- At the DN site, the highest dose calculated for the nine potential critical groups was 0.6 μSv (0.1% of the regulatory limit) for an adult from the Farm critical group. This dose is the same as the 2010 dose of 0.6 μSv, reported for the one-year-old infant from the Dairy Farm critical group. The change in critical group represents a very small relative shift in doses between the Farm and Dairy Farm groups, therefore the change in the most affected receptor is not significant.

- At the PN site, the highest dose calculated for the six potential critical groups was 0.9 μSv (0.1% of the regulatory limit) for an adult or 10-year-old child from the Urban Resident critical group. This dose is similar to the 2010 dose of 1.0 μSv reported for the same critical group.

Table 1: OPG Public Dose Estimates – 2011

Facility	Critical Group (Receptor)	Effective Dose (μSv)	Percentage of Legal Limit (%)	Percentage of Background Radiation around DN and PN (%)
Darlington Nuclear	Farm (Adult)	0.6	0.1	< 0.1
Pickering Nuclear	Urban Resident (Adult, 10 year old child)	0.9	0.1	0.1

Looking ahead in 2012, the REMPs will be upgraded to Environmental Monitoring Programs (EMPs) which will include consideration of exposure of humans to nuclear and hazardous substances and the exposure of non-human biota to nuclear and hazardous substances and physical stressors as required by CSA N-288.4-10. Phase 1 of the implementation of this upgrade is planned for completion by the end of 2012.

1.0 INTRODUCTION

Ontario Power Generation (OPG) owns and operates the Pickering Nuclear (PN) and Darlington Nuclear (DN) Generating Stations. To ensure nuclear activities at these stations are conducted in a manner that minimizes any adverse impact on the public and the natural environment, OPG has established an Environmental Management Program. This program is registered to the International Organization for Standardization (ISO) 14001 Environmental Management Systems standard.

As part of the implementation of this program, each station has a Radiological Environmental Monitoring Program (REMP), which monitors radiation in the environment surrounding the station to assess any radiological impact to the public. Samples are also collected from locations considered to be outside the influence of the PN and DN station operations to allow a baseline comparison with background values, and to allow determination of net values for dose calculations.

This annual REMP report is prepared and submitted to the Canadian Nuclear Safety Commission (CNSC) in accordance with the operating licenses issued to PN and DN. This report is also made available to the public.

The radiological emissions and environmental data collected for the period from January 1st to December 31st, 2011 for each site, their interpretations, and the estimates of radiation doses to the public resulting from the operation of PN and DN stations are provided in this report.

The radiological emissions and environmental data are summarized in Sections 3.3 and 5.0, respectively. The assessment of doses to the public is described in Section 7.0.

2.0 REMP OBJECTIVES

The OPG REMPs are designed to satisfy the following primary objectives:

(a) To demonstrate, independent of effluent monitoring, that nuclear site emissions of radioactive materials are properly controlled.

(b) To estimate annual doses to the public based on environmental data measured in the public domain.

(c) To provide data for evaluation of assumptions and transport models used to calculate station derived release limits and public doses.

3.0 OVERVIEW OF PICKERING AND DARLINGTON NUCLEAR STATIONS

3.1 Site Description

DN and PN Generating Stations have a combined generating capacity of about 6,600 megawatts (MW). A brief description of these two stations is as follows:

Darlington Nuclear

The DN Generating Station is an OPG CANDU (CANadian Deuterium Uranium) nuclear generating station. It is a four-unit station with a total output of 3,500 MW and is located on the shores of Lake Ontario in the Municipality of Clarington in Durham Region. It provides about 20% of Ontario's electricity needs, enough to serve a city of two million people.

DN also has the Tritium Removal Facility (TRF), where tritium is extracted from tritiated heavy water, and the Darlington Waste Management Facility for used fuel dry storage.

The immediate area around the Darlington station is mostly rural and farm lands with some industrial/commercial areas. The urban residential locations of Oshawa, Bowmanville and West/East Beach are more than 3 km from the site.

Based on the results of site-specific surveys, the residents around DN are grouped into nine categories which best represent their locations and/or lifestyle characteristics. The nine categories are: urban residents in Oshawa and in the community of Courtice, Bowmanville urban residents, West/East Beach urban residents, farmers, dairy farmers, rural residents, industrial/commercial workers, sport fishers, and campers.

Pickering Nuclear

The PN site is located on the shores of Lake Ontario, in the city of Pickering. The site contains the Pickering Nuclear (PN) Generating Stations and the Pickering Waste

Management Facility (PWMF) which consists of the Used Fuel Dry Storage and the Re-Tube Components Storage Area.

PN has six operating CANDU reactors. This station has a total output of 3,100 MW, enough to serve a city of one and a half million people. PN Units 2 and 3 are in safe shutdown state.

Unlike DN, the area around PN is mainly urban residential and industrial/commercial. The closest farm lands are more than 6 km from the station.

Based on the results of site-specific surveys, the residents around PN are grouped into six categories: inhabitants of a correctional institute, urban residents, farmers, dairy farmers, industrial/commercial workers and sport fishers.

3.2 Nuclear Generation Capacity

In 2011, OPG operated ten nuclear reactors that produced 48.4 terawatt hours (TWh) of electricity. This production is broken down as follows:

Darlington Nuclear DN's net electrical output in 2011 was 28.9 TWh.

Pickering Nuclear PN's net electrical output in 2011 was 19.5 TWh.

3.3 Radioactive Emissions Data

The radioactive emissions from DN and PN in 2011 remain at a very small fraction of the station Derived Release Limits (DRLs). These limits represent radionuclide release rates that correspond to an exposure at the legal public dose limit of 1000 microsieverts per year (μSv/a) by the most affected critical group. See Section 4.1 for the description of a critical group.

Table 3-1 shows the 2011 total airborne and waterborne emissions for radionuclides measured at the DN and PN sites as the annual activity released and as a percentage of the respective DRLs.

Table 3-1: OPG Annual Nuclear Site Emissions – 2011

Site Emissions	DN		PN	
	Bq	% DRL	Bq	% DRL
AIR				
Tritium Oxide	1.4E+14	0.34	5.5E+14	1.0
Elemental Tritium [(a)]	8.8E+13	0.01	NA	NA
Noble Gas [(b)]	2.2E+13	0.06	1.8E+14	0.63
^{131}I	1.5E+08	<0.01	2.4E+07	<0.01
Particulate	4.0E+07	<0.01	1.2E+07	<0.01
^{14}C	1.0E+12	0.06	1.8E+12	0.03
WATER				
Tritium Oxide	1.1E+14	<0.01	3.1E+14	0.06
Gross Beta/Gamma	3.1E+10	0.04	1.9E+10	0.40
^{14}C	1.9E+09	<0.01	2.2E+09	<0.01

NOTES: NA = Not Applicable, Bq = becquerels

(a) Emissions from Darlington Tritium Removal Facility (TRF)

(b) Units for noble gas emissions are γBq-MeV

3.3.1 Emissions Trends

Iodine and particulate in airborne emissions, and carbon-14 (C-14) waterborne emissions remain very low and have minimal contribution to public dose, therefore they are not trended. The 10-year trends of tritium and carbon-14 (C-14) emissions to air and tritium emissions to water from DN and PN are provided in Figures 3-1 to 3-7. Since the reported noble gas stack emissions are at times below the instrument detection limits, the results of environmental noble gas monitors are used to trend the station noble gas emissions, as described in Section 5.1.2.

Elemental Tritium Airborne Emissions

DN – Figure 3-1

As indicated in Figure 3-1, the elemental tritium (HT) emissions at DN have remained at low levels. In 2011, the HT emissions at DN were 8.8×10^{13} becquerels (Bq). The elevated HT emissions in 2004 and 2005 had minimal impact on public dose and were the result of a rupture disk failure at the TRF, which has since been corrected.

PN

PN has no HT emissions as it does not have a TRF which is a producer of HT.

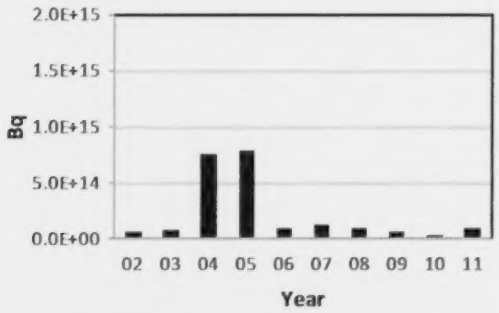

Figure 3-1: Darlington Nuclear Airborne Elemental Tritium Air Emissions

Tritium Oxide Airborne Emissions

DN – Figure 3-2

DN tritium oxide (HTO) airborne emissions have remained stable over the last five years. The 2011 HTO airborne emission was 1.4 x 10^{14} Bq.

PN – Figure 3-3

PN HTO airborne emissions continue to trend downwards since 2008 as a result of improvements in leak management, reliability and operation of vapour recovery dryers, and reduction of HTO source terms. These improvements were initiatives led by the station Tritium Reduction Team. Airborne HTO emissions in 2011 were 5.5 x 10^{14} Bq.

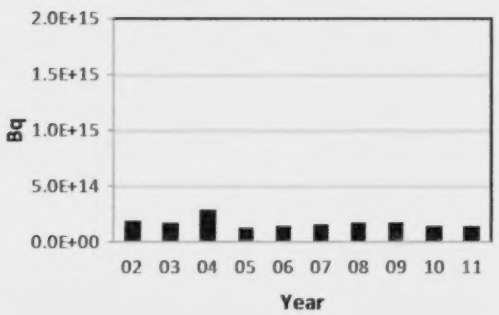

Figure 3-2: Darlington Nuclear Tritium Oxide Air Emissions

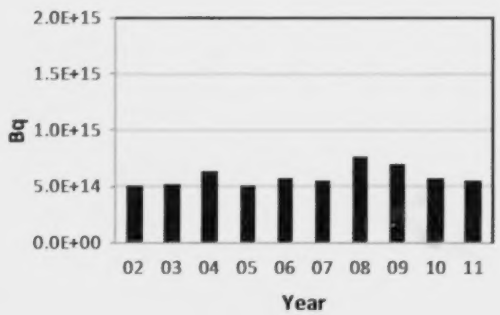

Figure 3-3: Pickering Nuclear Tritium Oxide Air Emissions

Carbon-14 Airborne Emissions

DN – Figure 3-4

DN C-14 airborne emissions have remained stable since 2004. The 2011 C-14 airborne emissions were 1.0×10^{12} Bq.

PN – Figure 3-5

PN C-14 airborne emissions have been trending down since 2007. The prior upward trend was due to a failed calandria tube that leaked carbon dioxide (CO_2) from the annulus gas into the Unit 7 moderator system. Moderator purification was increased in response to the leak to minimize airborne C-14 emissions. The emission level has returned to pre-2005 levels following the April 2008 replacement of the failed calandria tube. The 2011 C-14 airborne emissions were 1.8×10^{12} Bq.

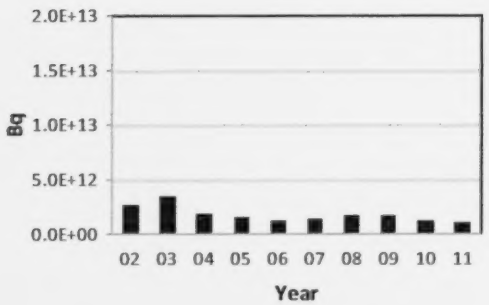

Figure 3-4: Darlington Nuclear C-14 Air Emissions

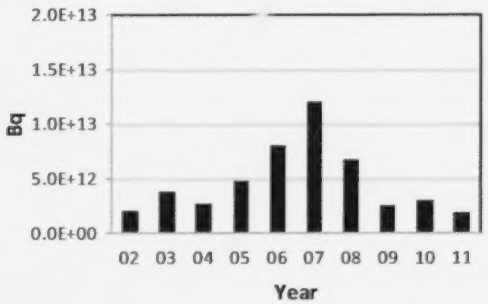

Figure 3-5: Pickering Nuclear C-14 Air Emissions

Tritium Oxide Waterborne Emissions

DN – Figure 3-6

DN HTO to water emissions have trended down since 2008. The upward trend from 2004 to 2008 was due to contamination of the autosampler, which is not reflective of a true increase in emissions, the drainage of the Emergency Coolant Injection (ECI) system, and discharges of Vacuum Building Dousing Water in 2007 and 2008 to prepare for the 2009 Vacuum Building Outage (VBO). The 2011 DN tritium to water emission was 1.1×10^{14} Bq.

PN – Figure 3-7

The PN waterborne HTO emissions were slightly elevated in 2008 and 2009, but have since returned to the levels observed prior to 2008. The increases in 2008 and 2009 were due to a minor heavy water leak from a Unit 1 shutdown cooling heat exchanger and a small Unit 1 boiler tube leak, respectively. The leak was subsequently contained and the water was sent to the upgraders for recovery. Repairs to both the shutdown cooling heat exchanger and boiler tube leaks were completed during the 2010 VBO

and HTO emissions have since decreased. The PN tritium to water emissions in 2011 were 3.1 x 10^{14} Bq. This is slightly higher than the 2010 emissions because all units were shut down during the 2010 VBO.

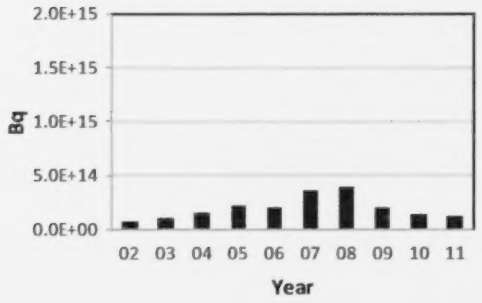

Figure 3-6: Darlington Nuclear Tritium Oxide Water Emissions

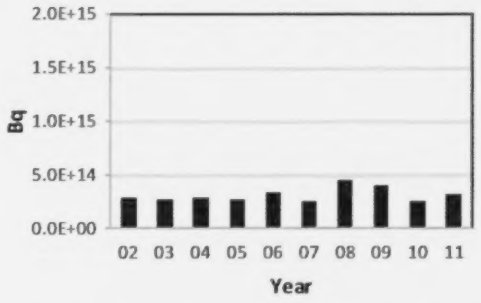

Figure 3-7: Pickering Nuclear Tritium Oxide Water Emissions

Gross Beta-Gamma Waterborne Emissions

Gross beta-gamma waterborne emissions for DN were not trended because its emission levels and contribution to public dose were minimal over past years, and remain so.

PN – Figure 3-8

PN gross beta-gamma emissions to water have trended down in 2011. The increase in 2009 and 2010 was due, as confirmed by a third-party review of the station in-house investigations, to anomalous samples of high activity. The 2010 emissions contributed to less than 0.2 μSv of the estimated 2010 public dose. In 2011, emissions dropped back down to the levels seen prior to 2009. The third-party review report recommended areas for further investigation. Implementation of these actions is currently in progress and targeted for completion by the end of 2012.

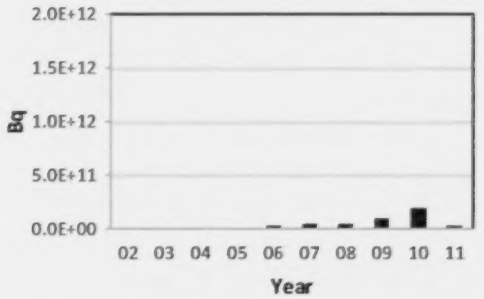

Figure 3-8: Pickering Nuclear Gross Beta-Gamma Water Emissions

3.4 OPG Nuclear Carbon-14 Inventory Data

The C-14 inventories within the PN and DN stations are included in this report to fulfill a regulatory commitment to the CNSC. The 2011 estimates of C-14 inventory within the PN and DN stations are 8.1 $x10^{14}$ Bq and 6.3 $x10^{14}$ Bq, respectively [R-2].

4.0 SAMPLING AND ANALYSIS PLAN

To ensure the local members of the public living and working around a nuclear power station are properly protected from any station radionuclide emissions, various exposure pathways, such as food ingestion, inhalation, and water ingestion (as shown in Figure 4-1, Model of Exposure Pathways from Station Emissions) were evaluated and assessed in the design of the OPG REMPs.

The significant human exposure pathways and radionuclides for the most affected receptors are routinely monitored so that the best estimate of site public dose can be performed. To do this, a site-specific survey is conducted in the areas within approximately a 10 km radius from DN and PN sites. Data from the site-specific surveys are used to establish the lifestyle characteristics (e.g., drinking water sources, consumption of local products, etc.) of the population around the sites and to identify the various potential critical groups for each site as defined in Section 4.1. Also, a site-specific pathway analysis is performed to identify the important radionuclides and human exposure pathways. The results of these two studies, along with the REMP governing documents and individual site programs, form a basis for establishing the annual sampling plan for the site REMPs.

Every five years, the site-specific survey and pathway analysis are reviewed and the sampling plans are updated based on the results. However, the next site-specific survey reviews will be in 2012, to align with the five-year frequency of the release of Census of Canada data so that the most up-to-date census information will be used.

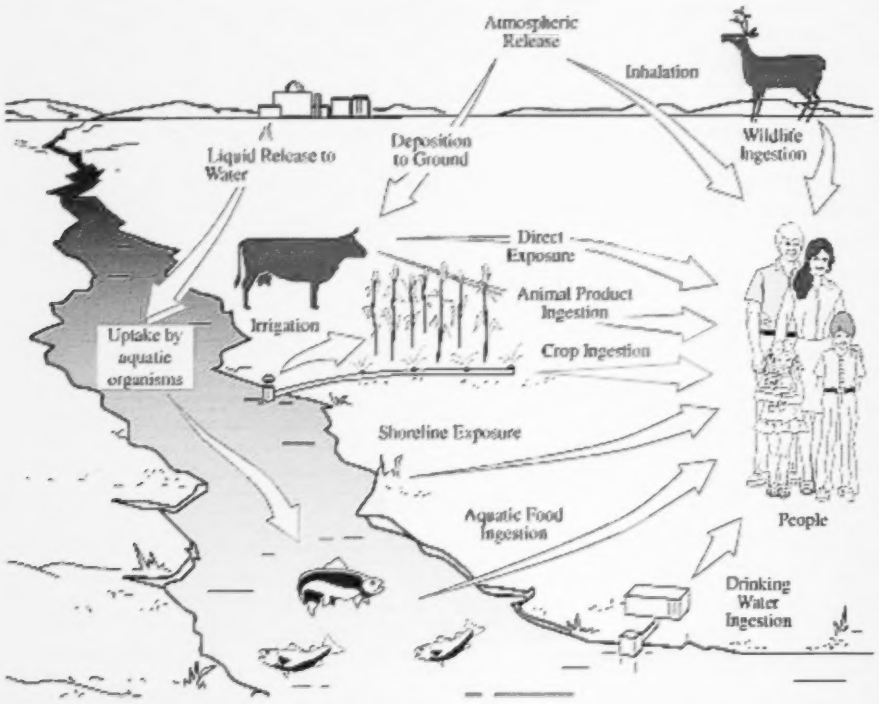

Figure 4-1: Model of Exposure Pathways from Station Emissions
Source: Based on United States Department of Energy/Hanford Site

4.1 Critical Groups and Representative Person

Members of the public living near the nuclear generating stations are represented using the "Critical Group" concept. Doses received by individual members of the public, as a result of station operations, vary depending on factors such as proximity to the station, diet, behavioural habits, age, and variations in environment. Individuals who form a homogeneous group with respect to these exposure factors can be grouped together into "potential critical groups". An individual with the average characteristics of the group is known as the "Representative Person" as described in CSA N288.1-08 [R-11].

The site-specific surveys identified six potential critical groups at the PN site and nine potential critical groups at the DN site. The critical group, and corresponding Representative Person, that receives the highest annual dose may vary from year to year; therefore doses are calculated for all potential critical groups. The highest estimated potential critical group dose for each site establishes the official public dose for that site.

4.2 REMP Sampling Plan

The REMP sampling plan outlines the radionuclides monitored, the locations, sample types and frequency of collection. Table 4-1 summarizes some of this information.

Samples are collected at station boundary locations as well as at critical group locations. Boundary locations are generally located close to the station perimeter. In Appendix D tables, the following represent boundary locations: D1, D2, D3, D4, D5, D6, P2, P3, P4, P6, P7, P8, P9, P10, and P11. Critical group sample locations are at the location of critical group members. For sample types that are not available at critical group locations, radionuclide concentrations at the critical group are estimated from concentrations at the boundary locations using ratios of modeled atmospheric dispersion factors.

The required sample media and locations are reviewed every five years after the site-specific surveys have been conducted. In the most recent reviews [R-27] [R-28], the existing REMP sampling programs were found to fulfill the sampling requirements for dose assessment purposes.

4.2.1 Radionuclides Monitored

Radionuclides that are emitted from PN and DN station operations are monitored in the REMPs and are listed below. The specific sample analyses used in the public dose calculation are indicated in Table 4-1.

C-14 – is produced from the operation of nuclear stations. It is also a naturally occurring radionuclide and a by-product of past nuclear weapons testing with average background concentrations between 220 becquerels per kilogram carbon (Bq/kg-C) to 240 Bq/kg-C. C-14 values detected above background are included in the dose calculation.

HTO – is a tritiated water molecule. T is used to represent an H-3 atom. HTO is a normal station emission of CANDU plants. Concentrations measured in plants and animals refer to the HTO concentration in the free water portion of the sample.

HT – is a tritiated hydrogen gas molecule. HT is present in the atmosphere as a result of the emissions from the TRF at DN. Pickering does not have HT emissions. HT concentration in air is modeled from emissions and not monitored in the environment. However, some HT is converted to HTO in the environment, and this HTO is monitored.

Organically Bound Tritium (OBT) – is tritium that is bound to the organic molecules in organisms and is not readily exchanged with other hydrogen atoms. OBT is incorporated during the formation of plant and animal products where HTO is present. OBT is monitored by OPG but sample results are not used in dose calculations as a standard method for the measurement of OBT in environmental samples still needs to be established. OBT concentrations are currently modeled from HTO concentrations measured in sample media at each critical group location and in fish. OPG dose

calculations incorporate dose from OBT via intake of terrestrial plants and animal products, and from fish.

Noble Gases – Radioactive noble gases released from the DN and PN plants are mostly Argon-41 (Ar-41), Xenon-133 (Xe-133) and Xenon-135 (Xe-135). The environmental detectors that measure noble gas doses may also detect Iridium-192 (Ir-192) skyshine from industrial radiography carried out in the stations. They also detect the external gamma dose from I-131 in air.

Iodine-131 (I-131) – The dose from radioiodine emissions is calculated from I-131 emissions, with the assumption that I-131 emissions are accompanied by an equilibrium mixture of other short lived iodine fission products (i.e., I-132, I-133, I-134 and I-135) or mixed fission products [I(mfp)]. I-131 is monitored in milk, but is not normally detected; therefore concentrations modeled from emissions are used for dose calculations.

Particulates and gross beta-gamma – Atmospheric particulate emissions are represented by Cobalt-60 (Co-60) and liquid effluent beta-gamma emissions are represented by Cesium-137 (Cs-137) as this provides the most conservative assignment of dose. Cs-137 is also present in the environment as a result of historic weapons testing. Cobalt-60 (Co-60) and Cesium-134 (Cs-134) are representative of station emissions and are analyzed together with Cs-137, which helps distinguish between the Cs-137 resulting from station operations and that from weapons testing.

Table 4-1: Environmental Samples Used for the Darlington and Pickering REMPs

Environmental Medium of Interest	Monitored For	Sampling Frequency	Analyses Frequency
SAMPLES USED FOR PUBLIC DOSE CALCULATIONS			
Atmospheric Sampling			
Air	HTO (active monitor)	Continuously	Monthly
Air	C-14 (passive monitor)	Continuously	Quarterly
Air	Noble gases (Ar-41, Xe-133, Xe-135), Ir-192*	Continuously	Reported monthly
Terrestrial Sampling			
Fruits, Vegetables, Silage	HTO and C-14	Annual (harvest)	Annual
Milk	HTO and C-14	Weekly	Monthly composite
Aquatic Sampling			
Municipal Drinking Water**	HTO	2-3 times/day	Weekly composite
Well Water	HTO	Monthly	Monthly
Lake Water	HTO	Monthly	Monthly
Fish	HTO, C-14, Cs-137, Cs-134, Co-60	Bi-annual (June and November)	Annual
Beach Sand	Cs-137, Cs-134, Co-60	Annual	Annual
SAMPLES FOR OTHER REMP OBJECTIVES			
Air	Noble gases (Thermoluminescent dosimeter), I-131	Continuously	Quarterly
Precipitation	HTO	Monthly	Monthly
Dry/Wet Fallout	Gross beta	Monthly	Monthly
Fruits, Vegetables, Silage	OBT	Annual (harvest)	Annual
Garden and Inland Soils	Cs-137, Cs-134, Co-60	Annual (harvest)	Annual
Milk	I-131	Weekly	Weekly composite of locations
Milk	OBT	Weekly	Monthly
Municipal Drinking Water**	Gross beta	2-3 times/day	Monthly composite
Well Water	Gross beta	Monthly	Quarterly composite
Fish	OBT	Bi-annual (June and November)	Annual
Sediment	C-14, Cs-137, Cs-134, Co-60	Every five years	Every five years
Lake water	Potassium	Every three years	Every three years

*Air kerma is measured and converted to external air immersion dose.
**Sampling frequency is quarterly for provincial locations.

4.2.2 Atmospheric Sampling

Samples of air, precipitation, and fallout are collected to monitor the environment around the DN and PN sites. Background samples are also collected to provide a comparison benchmark and to allow determination of net values for dose calculations. The radionuclide analyses performed and the sample collection frequency are detailed in Table 4-1 and discussed below.

The results of atmospheric sampling are summarized in Section 5.1 and detailed data is given in Appendix D, Environmental Monitoring Data, Tables D1 to D5.

4.2.2.1 Air

Tritium Oxide

HTO in air around PN and DN was previously sampled continuously by two technologies; the molecular sieve (active) sampler and the passive sampler. In 2010, the passive sampler was discontinued due to its inconsistent performance and incapability of providing accurate measurements, as demonstrated in an assessment conducted on the variability and accuracy of the active and passive tritium-in-air samplers. The assessment was based on the results of a 2006 CANDU Owners Group (COG) study [R-5] and the results of an OPG seven-month field test in 2009 using the passive sampler recommended by COG [R-30]. This assessment also concluded that active samplers provide accurate measurements of HTO in air and are the preferred HTO in air sampling method [R-30].

As the active samplers were aging and spare parts for key components were no longer available, by the end of 2011, all existing active samplers were replaced with new active samplers recommended by COG [R-38].

The active sampler collects water vapour by passing air continuously at a steady rate through two molecular sieve canisters in series. The active samplers are located at six site boundary REMP monitoring locations around DN and nine around PN, as identified in Figures C1 and C2 in Appendix C. These samples are collected and analyzed monthly.

The background concentration of HTO in air is measured at the Nanticoke location which is considered to be far from the influence of OPG nuclear stations.

Carbon-14

C-14 in air is sampled using passive sampling technology. The passive C-14 sampler works by absorption of CO_2 in air into soda lime pellets exposed for a period of an annual quarter. Samples are analyzed after each quarter.

C-14 in air concentrations were measured at 10 critical group locations around DN and three site boundary locations, and at eight critical group locations around PN, three of which are also site boundary locations. Since C-14 in air is not a significant dose pathway via inhalation, it is not necessary to measure C-14 in air at all boundary locations. Only the high wind frequency sectors were chosen as site boundary monitoring locations for PN and DN.

Background concentrations of C-14 in air were measured at six locations considered to be far from the influence of OPG nuclear stations.

Noble Gas Detectors

External gamma radiation doses from noble gases, Ir-192, and I-131 are measured using sodium iodide (NaI) spectrometers set up around the DN and PN sites. There are a total of seven detectors around the DN site boundary and nine detectors around

the PN site boundary. These detectors continuously monitor doses and an annual total is used in the dose calculation, with the exception of dose from I-131 which is modeled from emissions as per Section 4.2.1. Natural background dose has been subtracted from noble gas detector results.

Thermoluminescent Dosimeters

TLDs measure total gamma dose from background, as well as any gamma emitting radionuclides in the air or radiography skyshine. Any normal station contribution is too small to be distinguished from the high and variable contribution from natural background because TLDs do not distinguish between different contributing radionuclides. However, a significant station emission would be captured by the TLD at levels where the noble gas detectors may become saturated.

A total of six TLDs are placed around the DN site boundary and four TLDs are located at critical group locations. PN has a total of nine TLDs around the site boundary and one TLD at a nearby critical group location.

Background measurements are taken at 11 locations around Ontario.

All TLDs around DN, PN and at background locations are collected and analyzed every quarter.

4.2.2.2 Precipitation and Wet/Dry Fallout

Precipitation and wet/dry fallout samples are collected monthly and analyzed for HTO and gross beta activity. Precipitation data are not used in the calculation of public dose but the long-term data assists in understanding other indicators such as HTO in biota and HTO which will eventually reach the shallow drinking water well aquifers.

Six locations around DN and six locations around PN are measured. Precipitation and wet/dry fallout samples are not obtained from background locations.

4.2.3 Terrestrial Sampling

Terrestrial biota receives exposure from both airborne and waterborne emissions, as indicated in Figure 4-1. Cow's milk, for example, is affected by the air, plants, and various water sources that the cow consumes. It is therefore important to consider the combined effect of all these pathways when assessing the station impact on terrestrial samples.

Samples of soil, fruits, vegetables, milk and honey are collected to monitor the environment around the DN and PN sites. Background samples are also collected to provide a comparison benchmark and to allow determination of net values for dose calculations. The radionuclides monitored and the sample collection frequency are summarized in Table 4-1 and discussed below.

The results of terrestrial sampling are summarized in Section 5.2 and detailed data are given in Appendix D, Tables D6 to D9.

4.2.3.1 Garden and Inland Soils

As part of the operation of OPG nuclear stations, very small amounts of Cs-134, Cs-137 and Co-60 are released to the environment. These radionuclides can deposit on surrounding soil from the atmosphere and through irrigation. Soil samples around DN, PN, and background locations are collected and analyzed for gamma emitters to establish if OPG operations are having an effect on the surrounding soils, particularly if there is any accumulation over time. Soil data are not used in the calculation of public dose but the long-term trend assists in understanding and verifying transfer model calculations.

Three samples of garden soils and two open field (undisturbed soil) samples are obtained at local farms and residences close to the DN site.

One garden soil and one open field sample are obtained from location P11 located NW of the PN site.

Replicate soil samples are collected from three background locations (Cobourg, Goderich, and Lakefield).

4.2.3.2 Fruits, Vegetables, Silage and Honey

Samples of fruits, vegetables and silage representative of the growing season were taken from the vicinity of the DN and PN sites. Analyses were carried out for C-14 and HTO.

Sample locations, from which fruit, vegetable and silage samples were taken, in background locations and the areas surrounding DN and PN are shown in Appendix C, Maps of Environmental Monitoring and Critical Group Locations, Figures C1 to C3. Where multiple sample types were available (e.g., carrot and corn at a given location) the samples were combined into composites for analysis.

A total of 29 fruit and vegetable samples were obtained from various critical group locations around DN along with five silage samples. The population around PN is much more urban and, as a result, fewer residents in the surrounding areas grow their own fruits and vegetables. A total of 17 samples were collected from critical group locations around PN including one locally grown silage sample. Vegetables were sampled from five background locations.

Honey samples are not used in the dose calculation as dose from honey is modeled from air emissions. Nevertheless, a number of commercial apiaries are located in the DN and PN area from which honey samples were obtained and analyzed for HTO, C-14, and gamma emitters. Honey data were compiled from 2003 to 2011, which showed that C-14 and gamma results have been historically consistent, and HTO trends correspond roughly to the trends seen in boundary HTO in air and HTO in vegetation. The only exception is one anomalous result in 2011 for HTO in honey at PN location R154. It is expected this was a one-time, abnormal occurrence that is not indicative of any trend. This is supported by the fact that the location nearest to R154, F13 (located

within the same wind sector and closer to PN), had 2011 HTO in vegetation results that remained low and very much in line with historical values. Honey from R154 will be sampled in 2012 to confirm that its result falls back within the expected range.

4.2.3.3 Milk

Milk sampling is used to estimate the portion of dose received from milk ingestion for the Dairy Farm critical group. Milk consumed by other members of the public comes from a commercial dairy whose product consists of a composite from many dairy farms across Ontario. Values in this report are only applicable to residents of the surrounding dairy farms consuming raw milk and are not representative of milk that is sold at a grocery store.

Milk samples are collected weekly from dairy farms around DN and PN. For each of the site programs (DN and PN), a portion of the weekly samples from all dairy farms is combined to form a weekly composite sample and analyzed for I-131 to minimize losses by decay. At the end of the month, a portion of the weekly samples from each farm is combined to form a monthly composite for each farm and analyzed for HTO and C-14. Quarterly samples from background locations are collected and analyzed for HTO, C-14 and I-131.

Milk samples are collected from five dairy farms around DN, two dairy farms around PN and two dairy farms in background locations.

4.2.4 Aquatic Sampling

Samples of drinking water sources (municipal and well water), lake water, lake sediment, beach sand and fish are collected to monitor the aquatic environment around the DN and PN sites. Background samples are also collected to provide a comparison benchmark and to allow determination of net values for dose calculations. The radionuclides monitored and the sample collection frequency are detailed in Table 4-1 and discussed below.

The results of aquatic sampling are summarized in Section 5.3 and detailed data is given in Appendix D, Tables D10 to D13.

4.2.4.1 Lake Water and Water Supply Plants

Samples of drinking water are taken during each 8-12 hour shift at water supply plants (WSPs) that supply water to Durham Region and the City of Toronto. Weekly composites of these samples are analyzed for HTO, and monthly composites are analyzed for gross beta activity.

The locations of the WSPs sampled relative to the nearest nuclear station discharge are indicated in Table 4-2.

Table 4-2: Water Supply Plants Monitored and Distance from Stations

	Distance from Site
DN AREA WSPs	
Bowmanville WSP	7 km ENE of DN
Newcastle WSP	13 km E of DN
Oshawa WSP	8 km W of DN
PN AREA WSPs	
R.C. Harris WSP	22 km WSW of PN
Horgan WSP	11 km SW of PN
Ajax WSP	7 km ENE of PN
Whitby WSP	12 km ENE of PN

Lake water samples (non-drinking water) from three beach area locations around PN and three beach area locations around DN are collected and analyzed monthly for HTO and quarterly for gross beta activity.

Background grab samples are taken quarterly from drinking water supplies throughout the province and analyzed for HTO and gross beta activity.

4.2.4.2 Well Water

Monthly well water samples are collected from 15 wells around the DN area (seven farms/dairy farms and eight residential locations).

Monthly well water samples are collected from five wells around the PN area.

Samples are analyzed monthly for HTO and quarterly for gross beta activity.

4.2.4.3 Fish

At the DN site, fish sampling takes place over the cooling water discharge diffuser. At the PN site, the sampling location is in the PN outfall. Background samples were previously taken from the New York side of Lake Ontario. However, due to an unreliable fish supply, the background location was changed in 2011 to the Bay of Quinte area of Lake Ontario, which is a sufficient distance away from the influence of the stations.

- Target fish species to be collected at each site and at background locations are Lake Whitefish and White Sucker, with Round Whitefish and Brown Bullhead as their respective backup species.
- Eight replicate fish samples for two different species are collected and analyzed at each location.

- Four replicate samples of pan fish (i.e., crappie, sunfish, etc.) are obtained from McLaughlin Bay in Darlington Provincial Park, as campers are known to fish in this area.

- HTO, C-14, Co-60, Cs-134, Cs-137, and Potassium-40 (K-40) measurements are performed on each fish sample.

4.2.4.4 Sediment

Sediment samples are not utilized in the dose calculation and historical data has shown no indication of accumulation. Therefore, starting in 2010, the frequency of sample collection was reduced to once every five years. There were no samples collected in 2011.

4.2.4.5 Beach Sand/Silt Samples

Sand/silt from beaches around DN and PN sites is collected annually as it represents a potential pathway for external dose. Gamma spectrometry is performed on these samples.

Beach sand samples were collected at Cobourg to determine the Cs-137 concentration in Lake Ontario background sand due to atmospheric weapons test fallout. Wave action continuously moves the beach sand around disturbing the original deposition patterns of cesium and, as a result, it is not possible to establish accumulation unless the concentrations of Cs-137 are significantly higher than background.

4.2.5 Sewage Sampling

The Duffin Creek Water Pollution Control Plant (WPCP) is located about 2 km east of the PN site. The WPCP treats sewage effluent streams from the PN site and from York-Durham Regions, and a portion of the resulting sludge is incinerated. It is important to note that there is radioactivity in the sewage streams from sources other than PN, primarily from the use of radionuclides in medical diagnosis and treatment.

4.2.5.1 WPCP Incinerator Ash

WPCP incinerator ash is collected as it is the form of sewage that has the highest concentration of gamma emitting radionuclides and has the potential to cause the highest dose to WPCP workers. Monthly samples of ash are analyzed by high resolution gamma spectrometry.

4.2.5.2 PN Sewage Effluent

PN sewage effluent contains only a very small amount of incidental radioactivity from showers, toilets, janitorial sinks, etc. Since WPCP ash contains radionuclides from other sources such as medical treatment, PN sewage effluent is analyzed to determine the radioactivity of sewage leaving the property boundary that will end up at the

WPCP. Weekly samples of PN sewage are analyzed for gamma emitters and quarterly composite samples, made up from the weekly samples, are analyzed for HTO and C-14.

5.0 RESULTS OF ENVIRONMENTAL MONITORING DATA

This section contains the results of the environmental monitoring programs for the DN and PN sites, and those of the provincial background locations. All sampling locations are shown in Appendix C, Figures C1 to C3.

Radionuclide concentrations in the environment are low and at times below levels which can be detected by routine analytical techniques. In these situations the analytical result is reported as being below the detection limit (Ld) or critical level (Lc).

Lc: The critical level is the level (relative to background) below which a quantity cannot reliably be measured. More specifically, the critical level is the largest value of the quantity for which the probability of a wrong conclusion that a quantity is present exceeds a specified probability [R-15]. The REMP uses a probability of 5%.

Ld: The detection limit is the level (relative to background) above which a quantity can confidently be measured. More specifically, the detection limit is the smallest value of the quantity for which the probability of a wrong conclusion that the quantity is not present does not exceed a specified probability [R-15]. The REMP uses a probability of 5%.

When reporting the environmental measurement values in the tables in Appendix D, the following protocols were used:

- If the sample analysis is lower than the Ld of the analytical method but higher than the Lc, the actual measurement is reported and is in bold type.
- If the measurement is less than the Lc, then "< Lc" is reported (for Appendix D Table D3, it is reported as Lc in italics).
- When measurement averages or other calculations are performed, they are calculated using actual results obtained even if they are below the Lc.
- Gamma spectrometer results are reported as "< Ld" when their actual values are below the Ld.

5.1 Atmospheric Sampling

5.1.1 Air

Tritium Oxide

The 2011 annual average results of airborne HTO measured by molecular sieve monitors at the DN, PN, and background sites are summarized in Appendix D, Table D1.

The annual average HTO in air measured at the background locations was consistently below the active sampler detection limit of 0.2 Bq/m^3.

The boundary average values provide a valid year-to-year comparison of the HTO in air concentration around the sites. Apart from the station emissions, which are the main contributor to HTO concentrations in air, the levels of HTO observed in the environment are also affected by the wind direction, wind speed, ambient humidity, and seasonal variations. As such, fluctuations from year to year are expected even if station HTO emissions remain constant.

In the past, the passive tritium-in-air samplers often gave higher results than the active samplers. To remain conservative, for locations where both sampling technologies were present, the higher result was used for the dose estimates. The use of the passive tritium-in-air samplers was discontinued as they were shown to be inaccurate and overestimated results, while the active samplers were shown to be accurate. Since the discontinuation of the passive samplers at the end of 2009, the annual boundary average of HTO in air has dropped. The impact is more apparent at PN than at DN since PN has higher measurements of airborne tritium.

DN – Figure 5-1

The 2011 HTO in air annual average concentrations measured at boundary locations ranged from 0.2 to 0.7 Bq/m^3. The average boundary concentration of 0.4 Bq/m^3 is consistent with those observed in the environment over the last five years which fluctuated between 0.5 and 1.0 Bq/m^3, as illustrated in Figure 5-1.

PN – Figure 5-2

The 2011 HTO in air annual average concentrations measured at boundary locations ranged from 1.1 to 11.5 Bq/m^3. The average boundary concentration of 4.4 Bq/m^3 is lower than those observed prior to the discontinuation of passive samplers at the end of 2009, as illustrated in Figure 5-2.

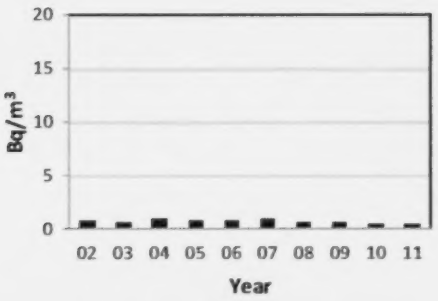

Figure 5-1: Darlington Nuclear Boundary Average HTO in Air

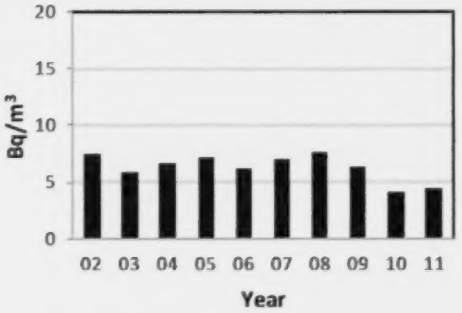

Figure 5-2: Pickering Nuclear Boundary Average HTO in Air

Carbon-14

The 2011 annual averages of airborne C-14 measured at the DN, PN and background sampling locations are summarized in Appendix D, Table D2.

C-14 is naturally occurring in the environment but is also a by-product of past nuclear weapons testing from the early 1960's. C-14 background concentrations around the world are currently decreasing as weapon test C-14 is removed naturally from the environment over time. Pre-atmospheric weapons test levels were measured at 226 Bq/kg-C [R-8]. The annual average C-14 in air concentration observed at background locations was 238 Bq/kg-C in 2011.

DN – Figure 5-3

The annual average C-14 in air concentrations measured at all DN sampling locations ranged from 224 to 265 Bq/kg-C. The 2011 C-14 in air average concentration measured at the three select high wind frequency boundary locations around DN was 250 Bq/kg-C. The long-term trend of C-14 in air, as illustrated in Figure 5-3, shows that the 2011 average is consistent with levels observed over the last five years.

PN – Figure 5-4

The annual average C-14 in air concentrations measured at all PN sampling locations ranged from 230 to 428 Bq/kg-C. The 2011 C-14 in air average concentration measured at the three select high wind frequency boundary locations around PN was 382 Bq/kg-C. The long-term trend of C-14 in air, as illustrated in Figure 5-4, shows that the average C-14 concentration in air remain similar to the previous two years and reflects the station C-14 airborne emissions trends over the last five years as discussed in Section 3.3.

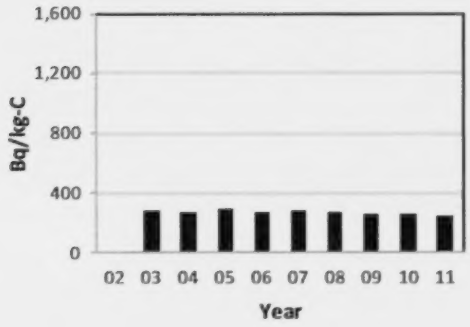

Figure 5-3: Darlington Nuclear Boundary Average C-14 in Air

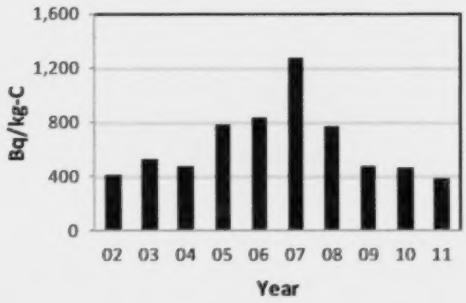

Figure 5-4: Pickering Nuclear Boundary Average C-14 in Air

5.1.2 External Gamma

Noble Gas Detectors

The annual boundary average noble gas dose rate is estimated from the monthly data from each detector. Results obtained in 2011 from the noble gas detectors are summarized in Appendix D, Table D3 and discussed below.

DN

Due to a different station design, DN does not experience the same level of emissions of noble gases as PN. The DN boundary average dose rates for Ar-41, Xe-133, Xe-135, Ir-192 and I-131 were all below the detection limits for the past five years. Thus, no trend graph is presented for DN.

PN – Figure 5-5

Ar-41 is the predominant radionuclide measured in noble gas around PN followed by Xe-135 and Xe-133. The PN boundary average Ar-41 dose in air was 1.1 microgray (μGy)/yr in 2011.

Ar-41 emissions and measurements in the environment are largely related to the number of operating days of PN Units 1 and 4. Figure 5-5 illustrates the trend of the boundary average Ar-41 dose rate for PN. The increasing trend of Ar-41 emissions starting in 2003 is the result of Unit 4 returning to service, and an additional contribution from Unit 1 returning to service in November 2005. In 2011, overall electricity power production remained similar to 2010, however the boundary average dose rate for Ar-41 decreased. This decrease was the result of repairs completed in 2011 to reduce air ingress via Unit 4 calandria vault dryers.

Xe-133 and Xe-135 were also measured above the detection limit at PN. Measured boundary average values in 2011 were 0.02 μGy/yr for Xe-133 and 0.08 μGy/yr for Xe-135, which are consistent with the their air doses observed in previous years.

Doses from Ir-192 and I-131 were below the detection limits.

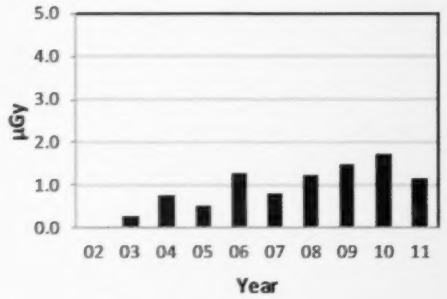

Figure 5-5: Pickering Nuclear Boundary Average Ar-41 Dose Rate in Air

Thermoluminescent Dosimeters

The 2011 annual average results from the TLDs at PN, DN and background sampling locations are summarized in Appendix D, Table D4. Figures 5-6 and 5-7 illustrate the trends in external gamma dose rates observed at DN and PN boundary locations over the last 10 years. TLD measurements are largely comprised of the natural background gamma dose with a small contribution from station emissions, while the noble gas detector results have the background dose subtracted (see Section 4.2.2.1 for more detail).

The 2011 boundary average external dose rates in air for the DN and PN sites remained consistent with the values established over the last 10 years. A small step change was observed in 2007 resulting from the replacement of the Panasonic TLD reader with the Harshaw TLD system. The difference was attributed to the difference in energy response between the two systems [R-3].

The 2011 background external total gamma dose rate in air averaged 508 µGy/yr from nine locations.

DN – Figure 5-6

The boundary average external total gamma dose rate in air for 2011 was 481 µGy/yr. This dose rate falls within the variability of natural background gamma.

PN – Figure 5-7

The boundary average external total gamma dose rate in air for 2011 was 466 µGy/yr. This dose rate falls within the variability of natural background gamma.

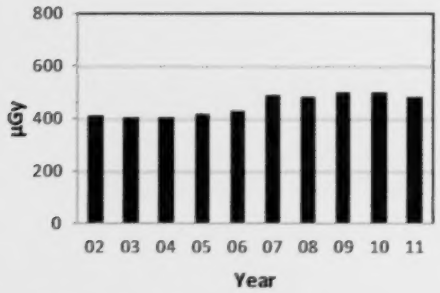

Figure 5-6: Darlington Nuclear Boundary Average TLD Gamma Dose Rate

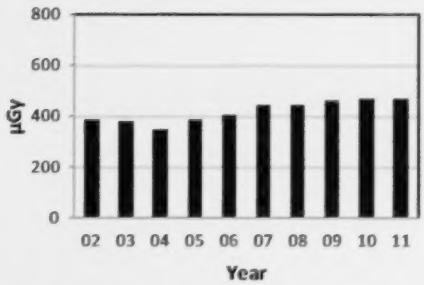

Figure 5-7: Pickering Nuclear Boundary Average TLD Gamma Dose Rate

5.1.3 Precipitation and Dry/Wet Fallout

Tritium Oxide

The 2011 annual average precipitation and wet/dry fallout sample results from DN and PN sampling locations are presented in Appendix D, Table D5, and annual trend plots of HTO in precipitation are shown in Figures 5-8 and 5-9.

HTO in precipitation values closely follow airborne HTO emissions trends (Figures 3-2 and 3-3).

DN – Figure 5-8

The DN boundary average tritium in precipitation concentration reflects the DN airborne tritium emissions trend which has been stable over the last five years. The 2011 boundary average was 21 Bq/L.

PN – Figure 5-9

The PN boundary average tritium in precipitation concentration reflects the PN airborne tritium emissions trend. The 2011 boundary average was 211 Bq/L.

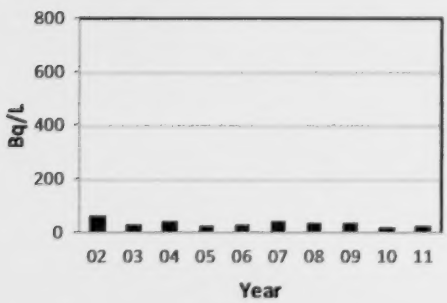

Figure 5-8: Darlington Nuclear Boundary Average HTO in Precipitation

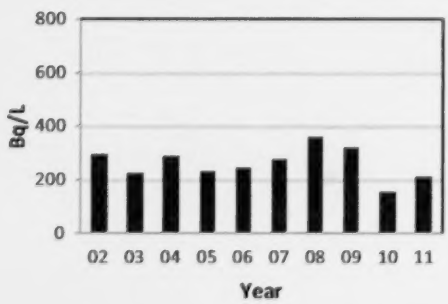

Figure 5-9: Pickering Nuclear Boundary Average HTO in Precipitation

Gross Beta

Measurements of gross beta activity in wet/dry fallout are reported in units of Bq/(m^2·month). These measurements represent the total fallout as a result of deposition of airborne radionuclides both as dry deposition and wet deposition (via precipitation). Gross beta in fallout in Canada normally averages from 5 Bq/(m^2·month) to 40 Bq/(m^2·month) on an annual basis due to radioactive fallout from natural sources (Berylium-7 [Be-7], K-40, Uranium (U) and Thorium (Th) series radionuclides in dust from surface soil and other natural sources) and atmospheric nuclear weapons testing [R-4]. The 2011 average measurements of 17.2 Bq/(m^2·month) and 18.5 Bq/(m^2·month) for the DN and PN sites respectively were within this range.

5.2 Terrestrial Sampling

5.2.1 Garden and Inland Soils

The results for garden and inland soils are provided in Appendix D, Table D6.

Gamma Spectrometry

Background values of Cs-137 are present in the soil as a result of historic weapons testing fallout. Co-60 and Cs-134, if detected, would be a result of emissions from DN or PN.

Cs-137 concentrations in background soil samples analyzed in 2011 ranged from 3.1 Bq/kilogram (kg) to 6.3 Bq/kg. All measured Cs-137 concentrations around the sites are within the range of values seen at the background locations over the last 10 years (from 0.4 to 12.5 Bq/kg). Neither Cs-134 nor Co-60 were detected in any PN or DN soil samples in 2011. It is therefore concluded that the Cs-137 measured in these soil samples is from historic weapons testing fallout and not from OPG operations.

DN

At the DN locations, Cs-137 in soil concentrations ranged from 2.8 to 4.4 Bq/kg. Cs-134 and Co-60 were not detected in any of the samples.

PN

At PN locations the Cs-137 in soil concentration was measured as 2.9 Bq/kg in the PN garden soil sample and 5.7 Bq/kg in the open area sample. Cs-134 and Co-60 were not detected in any of the samples.

5.2.2 Vegetation

The results for vegetation are provided in Appendix D, Table D7.

Tritium Oxide

The average HTO concentration measured in the vegetables at five provincial background locations was 3.9 Bq/L for 2011.

HTO concentrations in vegetation around the nuclear sites tend to vary from year to year due to prevailing winds, HTO emissions, humidity, etc. Furthermore, the number of samples and their locations have changed over the years. These variations should be noted when comparing long-term trends of HTO in vegetation surrounding the DN and PN sites as shown in Figures 5-10 and 5-11.

DN – Figure 5-10

Local fruit and vegetables collected around the DN site had HTO concentrations above the background average. The 2011 average concentration of HTO in vegetation was 12.7 Bq/L which is in the lower range of values observed in the last five years.

PN – Figure 5-11

Local fruit and vegetables collected around the PN site had HTO concentrations above the background average. The 2011 average concentration of HTO in vegetation was 55.7 Bq/L which is below the values observed in 2007 to 2008, and similar to 2010. This may be attributed to a downward trend in HTO emissions to air since 2008, and to the exclusion of an on-site vegetable sample location from the off-site average starting in 2009, since it was not representative of produce consumed by the public.

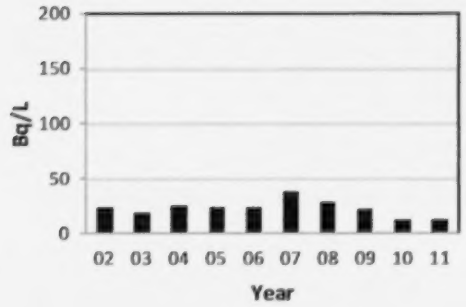

Figure 5-10: Darlington Nuclear HTO in Vegetation

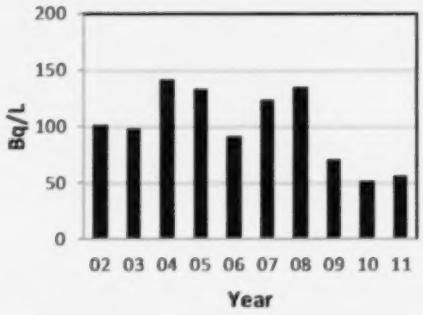

Figure 5-11: Pickering Nuclear HTO in Vegetation

Carbon-14

Background C-14 measurements have been trending downwards with time and are now similar to the conditions prior to weapons testing [R-26]. In 2011, the annual average C-14 in background vegetation was measured at 208 Bq/kg-C.

DN – Figure 5-12

The 2011 average concentration of C-14 in DN vegetation was 245 Bq/kg-C. Figure 5-12 indicates that over the long term, C-14 levels in vegetation around DN are stable and near background levels.

PN – Figure 5-13

For PN, the average C-14 concentration in vegetation for 2011 was 260 Bq/kg-C. Figure 5-13 illustrates the trend of C-14 concentration in vegetation around PN, which roughly follows the trend observed in station C-14 airborne emissions discussed in Section 3.3.

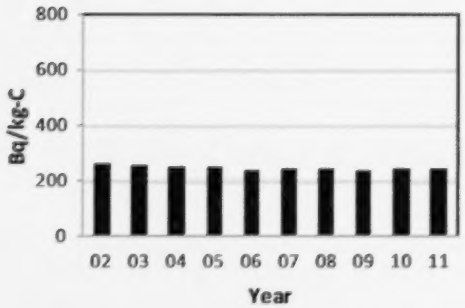

Figure 5-12: Darlington Nuclear C-14 in Vegetation

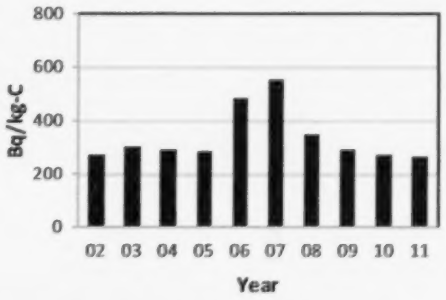

Figure 5-13: Pickering Nuclear C-14 in Vegetation

5.2.3 Milk and Silage

Annual average values of HTO and C-14 in milk and silage are provided in Appendix D, Table D9 and D7, respectively.

The annual average HTO and C-14 in milk measurements around the nuclear sites vary from year to year due to changes in prevailing winds, emissions, humidity, cow's diet, and water sources. Furthermore, the number and location of dairy farms sampled at both PN and DN have changed over the years, which should be noted when reviewing long-term trends.

Tritium Oxide

The background average HTO in milk concentration was 2.4 Bq/L, based on sampling at two farms outside the influence of the stations, which is below the Ld of 4.5 Bq/L.

As expected, both the DN and PN values of HTO in milk were above the background average concentration.

DN – Figure 5-14

At the DN site, the average level of HTO in milk was slightly below the Ld at 4.4 Bq/L in 2011 from five dairy farms located within 15 km of the site. The trend of HTO in milk shown in Figure 5-14 indicates that the 2011 value is in the lower range of values observed in the past five years.

PN – Figure 5-15

At the PN site, the average concentration of HTO in milk was 16.5 Bq/L in 2011 based on two dairy farms located within 12 km of the site. The PN trend for HTO in milk shows a decline since 2004 as illustrated in Figure 5-15.

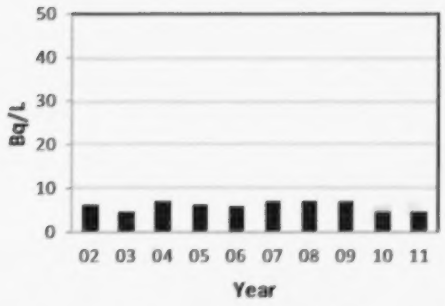

Figure 5-14: Darlington Nuclear HTO in Milk

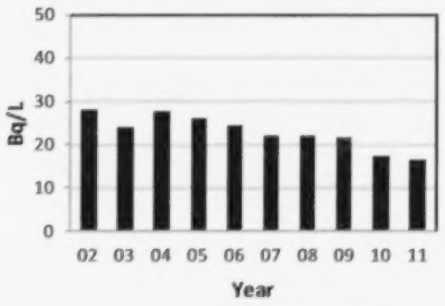

Figure 5-15: Pickering Nuclear HTO in Milk

Carbon-14

The background average C-14 in milk sampled from two farms on a quarterly basis was 237 Bq/kg-C. The 2011 C-14 levels in milk measured at the dairy farms around DN and PN were not significantly above background.

The C-14 level in silage consumed by the cows is the main contributing factor to the C-14 levels in milk. The silage contains C-14 from the previous year when it was grown, therefore emissions from the previous year would affect the C-14 values measured in milk in the current year.

DN – Figure 5-16

The 2011 average concentration of C-14 in milk at surrounding DN locations was 242 Bq/kg-C. Figure 5-16 indicates that over the long term, C-14 levels in milk around DN are stable and near background levels.

The average C-14 concentration in silage was 241 Bq/kg-C over five samples at DN (Table D7), which is within the range of values seen over the last five years.

PN – Figure 5-17

For PN, the average C-14 concentration in milk for 2011 was 247 Bq/kg-C. Figure 5-17 illustrates the trend of C-14 concentration in milk around PN. The concentration of C-14 in milk remains consistent with previous years and near background levels.

The C-14 concentration in silage was 210 Bq/kg-C from a single sample at PN (Table D7), which is below the range of values seen over the last five years.

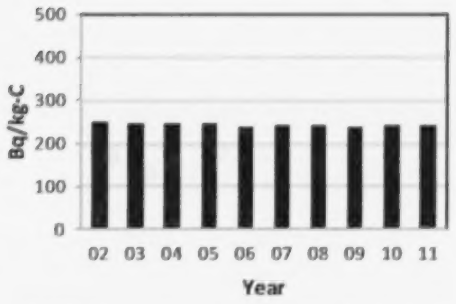

Figure 5-16: Darlington Nuclear C-14 in Milk

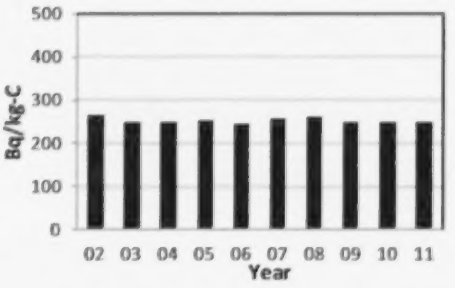

Figure 5-17: Pickering Nuclear C-14 in Milk

Iodine-131

In 2011, I-131 was not detected in any milk samples. The Ld for I-131 averaged approximately 0.1 Bq/L for all samples. This is consistent with previous years.

5.3 Aquatic Sampling

5.3.1 Lake Water and Water Supply Plants

The results for lake water and water supply plants are provided in Appendix D, Table D10.

The impact of HTO emissions from OPG stations on the nearby WSPs varies depending upon distance from the station, lake current direction, location and depth of the WSP intake pipe and general dispersion conditions. Annual average HTO levels at all WSPs were well below 7,000 Bq/L, which is the Ontario Drinking Water Quality Standard [R-29] for HTO. OPG also met its voluntary commitment to maintain annual average HTO levels at all WSPs below 100 Bq/L.

Tritium Oxide

HTO in Lake Ontario, along with all the Great Lakes, originates from several sources: natural cosmogenic tritium, residual tritium fallout from atmospheric weapons testing, current emissions from nuclear plants, and residual HTO from past emissions of nuclear plants. The total background concentration of tritium in Lake Ontario was measured at four locations farther than 40 km from either PN or DN (Brockville,

Burlington, Cobourg, and Kingston). The average annual concentration measured was 5.2 Bq/L, which includes residual HTO from previous years of emissions.

For the purpose of calculating public dose resulting from OPG operations, the sum of current emissions and residual HTO from past emissions was used. The background HTO value, subtracted from HTO measurements, included only natural cosmogenic tritium and residual weapons fallout tritium. This produces a conservative estimate of dose from tritium in lake water. This Lake Ontario background component for 2011 was conservatively estimated to be 1.6 Bq/L, using the Great Lakes Time-Concentration Tritium Model [R-6].

The monthly average HTO concentrations for 2011 at the Darlington and Pickering area WSPs are given in Figures 5-18 and 5-19.

The trend plots of all the WSPs annual average concentrations of tritium in drinking water are shown in Figures 5-20 through 5-26. In the past five years, the annual average tritium concentrations at all WSPs have remained less than 10 Bq/L.

DN – Figure 5-18

For WSPs located in the DN area, the 2011 annual average HTO concentrations measured at the Newcastle, Bowmanville and Oshawa WSPs ranged from 4.4 to 5.5 Bq/L, with background subtracted. HTO concentrations at these WSPs are consistent with results from previous years.

PN – Figure 5-19

The WSPs located in the PN area, Ajax, Whitby, Harris and Horgan, had 2011 annual average HTO concentrations between 4.4 and 5.8 Bq/L, with background subtracted. HTO concentrations at these WSPs are consistent with results from previous years.

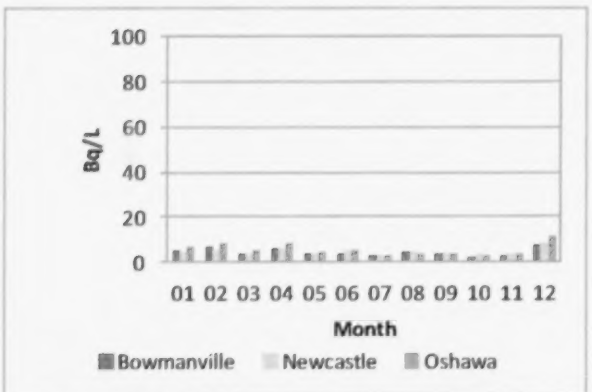

Figure 5-18: Darlington Nuclear WSPs 2011 Monthly HTO in Water Concentrations

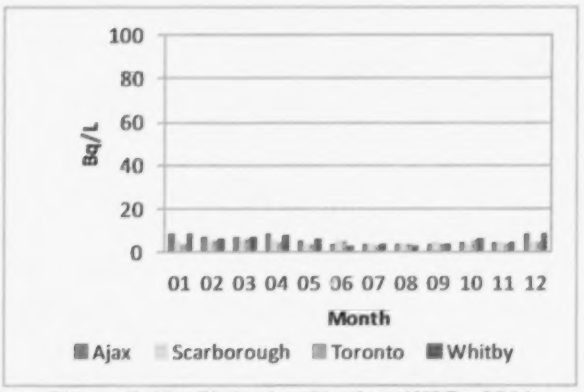

Figure 5-19: Pickering Nuclear WSPs 2011 Monthly HTO in Water Concentrations

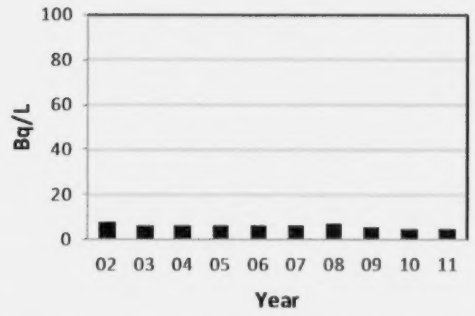

Figure 5-20: Bowmanville WSP – HTO in Water

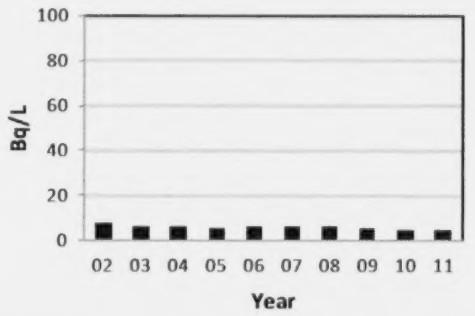

Figure 5-21: Newcastle WSP – HTO in Water

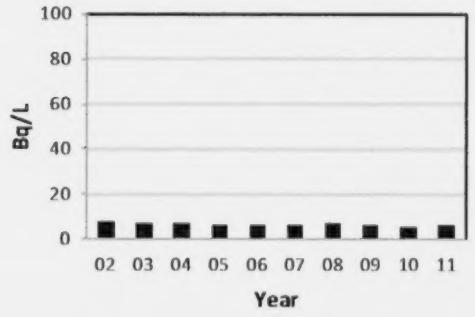

Figure 5-22: Ajax WSP – HTO in Water

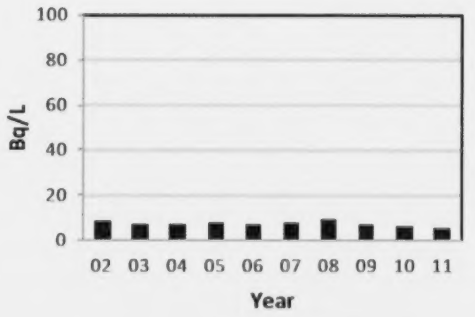

Figure 5-23: Oshawa WSP – HTO in Water

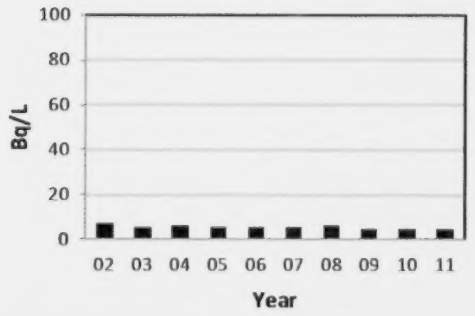

Figure 5-24: Scarborough Horgan WSP – HTO in Water

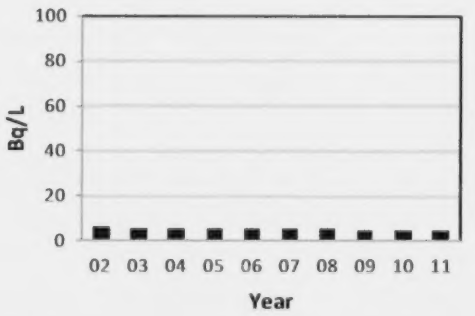

Figure 5-25: Toronto Harris WSP – HTO in Water

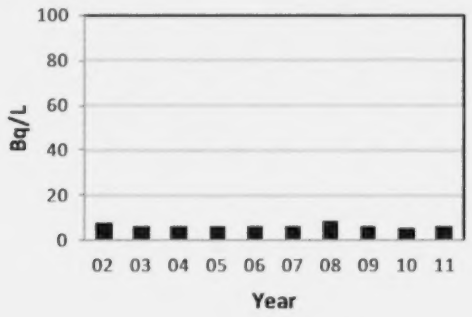

Figure 5-26: Whitby WSP – HTO in Water

Gross Beta

Annual average gross beta activity levels in samples from DN and PN area WSPs were both 0.10 Bq/L. These results are consistent with the average of the four provincial background Lake Ontario measurements of 0.10 Bq/L and are well below the gross beta activity screening level of 1 Bq/L, which is an internal OPG level as well as recommended by Health Canada [R-37].

5.3.2 Well Water

Monthly well water samples are collected from farms and residents near the DN and PN sites and results are in Appendix D, Table D10.

Tritium Oxide

HTO concentrations in well water depend on the depth of the well and thus the amount of time it takes for precipitation to reach the aquifer from where the well draws its water. Radioactive decay of the tritium during its transit time to the aquifer determines the residual activity level in the well water. Deeper wells tend to have lower HTO concentrations. Well water HTO concentrations reflect the level of past atmospheric HTO releases because of the time it takes for precipitation to reach the well.

DN

The maximum annual average HTO concentration observed in well water samples collected from the DN area was 22.4 Bq/L, which is consistent with the values seen over the last five years.

PN

The maximum annual average HTO concentration observed in well water samples collected from the PN area was 17.3 Bq/L, which is significantly lower than the maximum values seen in previous years. This is a result of the removal of R11 wells as this location is no longer a residential property and the wells are no longer in use. These wells normally had the highest HTO concentrations.

Gross Beta

DN

Samples from two residential wells around DN had gross beta activity higher than OPG's internal screening level of 1 Bq/L. The annual average gross beta activities at these two locations were measured as 2.3 and 1.3 Bq/L. Analysis was done to identify the specific radionuclide(s) responsible for the higher activity, and confirmed that the gross beta activity at these locations were due to naturally occurring K-40. Annual average gross beta activity from all other well water samples was below 0.5 Bq/L. These results are similar to those over the last five years.

PN

No gross beta activity in well water was measured for PN since the wells selected for analysis, at location R11, were removed from the REMP in 2011 as mentioned above.

5.3.3 Fish

The results for fish are provided in Appendix D, Table D11.

Tritium Oxide

The HTO levels in fish change quickly in response to changes in water HTO levels from station waterborne emissions. Thus, HTO concentrations measured in fish tissue reflect the HTO concentration in the water in the few hours before they were sampled. Long-term graphs of fish HTO levels for PN and DN are provided in Figures 5-27 and 5-28.

In 2011, the HTO in Lake Ontario background fish samples averaged 4.4 Bq/L.

DN – Figure 5-27

The HTO levels in the DN outfall fish samples averaged 3.9 Bq/L. This value is consistent with the levels observed over the last five years.

PN – Figure 5-28

The HTO concentration in the PN outfall fish samples averaged 8.9 Bq/L. This value is consistent with the levels observed over the last five years.

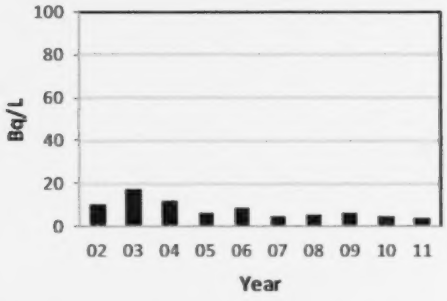

Figure 5-27: Darlington Nuclear HTO in Fish

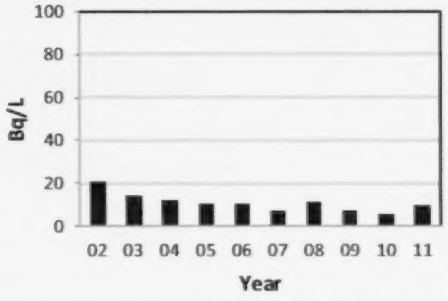

Figure 5-28: Pickering Nuclear HTO in Fish

Carbon-14

The average C-14 level in fish measured at a background Lake Ontario location was 221 Bq/kg-C in 2011.

The concentrations of C-14 in fish at both DN and PN for the past five years are consistent and comparable to background levels, as shown in Figures 5-29 and 5-30.

DN – Figure 5-29

The 2011 annual average C-14 level in DN fish was 255 Bq/kg-C.

PN – Figure 5-30

The 2011 annual average C-14 level in PN fish was 247 Bq/kg-C.

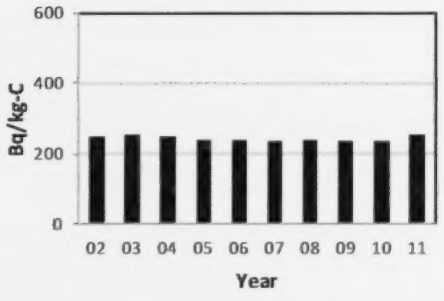

Figure 5-29: Darlington Nuclear C-14 in Fish

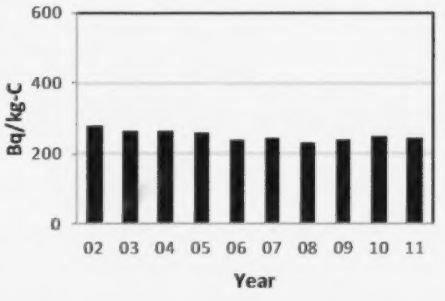

Figure 5-30: Pickering Nuclear C-14 in Fish

Gamma Spectrometry

The major portion of the gamma activity in fish is naturally occurring K-40. A small amount of Cs-137 is usually present primarily due to nuclear weapons testing and not reactor operation since Cs-134 and Co-60, which are indicative of reactor operation, were not detected.

The average Cs-137 value for background Lake Ontario fish was 0.4 Bq/kg.

Figures 5-31 and 5-32 illustrate that the Cs-137 levels in fish around DN and PN in the past five years are stable.

DN – Figure 5-31

The average Cs-137 value for DN fish was 0.2 Bq/kg, slightly below background. Cs-134 and Co-60, which are indicative of reactor operation, were not detected in any fish samples at DN site in 2011.

PN – Figure 5-32

The average Cs-137 values for PN fish was 0.2 Bq/kg, slightly below background. Cs-134 and Co-60, which are indicative of reactor operation, were not detected in any fish samples at PN site in 2011.

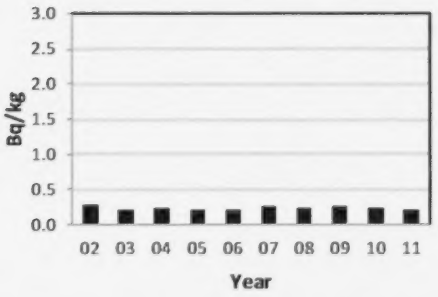

Figure 5-31: Darlington Nuclear Cs-137 in Fish

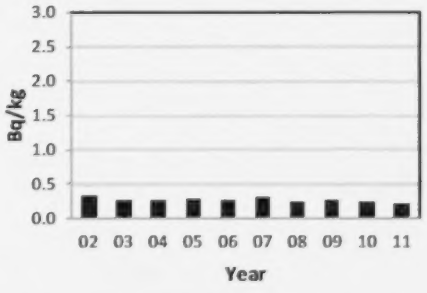

Figure 5-32: Pickering Nuclear Cs-137 in Fish

5.3.4 Sediment

As per Section 4.2.4.4, the frequency of lake sediment sampling has been reduced to once every five years. The results for sediment are provided in Appendix D, Table D12 are 2009 data. See the 2009 Results of REMPs report [R-36] for the discussion on results.

5.3.5 Beach Sand/Silt Samples

The results for beach sand/silt are provided in Appendix D, Table D13.

Gamma Spectrometry

Background Cs-137 concentrations in beach sand samples measured at Cobourg averaged 0.4 Bq/kg. These values are consistent with values observed over the past five years.

DN

The Cs-137 concentrations measured in DN beach sand samples ranged from 0.2 Bq/kg to 0.5 Bq/kg. Similar to previous years, there was no Co-60 or Cs-134 detected in the sample.

PN

The Cs-137 concentrations measured at PN area beaches ranged from 0.5 Bq/kg to 0.9 Bq/kg. Similar to previous years, there was no Co-60 or Cs-134 detected in the samples.

Wave action continuously moves the beach sand around, disturbing the original deposition patterns. This range of Cs-137 values is close to the background values measured and, without the presence of other radionuclides such as Co-60 or Cs-134 that are more closely related to reactor operation, the Cs-137 measured along the shoreline cannot be confirmed to be the result of OPG operations.

5.4 Sewage Sampling

The results for the PN sewage samples and the ash from the WPCP incinerator are provided in Appendix D, Table D14.

PN

The concentrations of I-131 in ash were above the detection level with an annual average of 6.5 Bq/L. However, I-131 was not detected in any of the PN sewage samples. These results strongly suggest that PN operations are not a major contributor to the I-131 detected in the WPCP ash samples. The ash sample gamma scans also identified other radionuclides of medical or industrial origin, but these are not quantified in this report.

5.4.1 PN Sewage Effluent – HTO and C-14

The average HTO concentration in sewage was 3111 Bq/L, which is higher than the level seen in 2010. The increase is the result of occasional spikes in HTO concentration, and is not indicative of any ongoing leak or discharge. Corrective actions have been implemented to address these spikes.

The measured HTO concentration has a very small dose implication (0.01 μSv) to the WPCP workers, which is 0.001% of the DRL. C-14 was not detected in any of the quarterly composite samples.

5.5 Special Studies and Other Studies

5.5.1 Special Studies

Special Studies are conducted to investigate specific REMP issues or findings. Special Studies exclude development work such as improvement of measurement techniques or instruments.

There are currently no issues in the REMPs that require a special study.

5.5.2 Other Studies

Cesium Bioaccumulation Factor (BAF) for Fish in Lake Ontario

Concentrations of potassium in lake water around PN, DN and Cobourg are monitored to support validation of the CSA N288.1-08 [R-11] default cesium bioaccumulation factor (Cs BAF) for fish of 3500, which is used for the calculation of station Derived Release Limits (DRLs). The usage of the CSA N288.1-08 recommended Cs BAF of 3500 for DRL calculations is valid. As indicated in last year's report [R-36], this study will be conducted every three years. As a result, the next potassium in lake water measurements will take place in 2013 to revalidate the default Cs BAF value.

6.0 ATMOSPHERIC MODELLING

6.1 Integrated Model for Probabilistic Assessment of Contaminant Transport (IMPACT)

The IMPACT version 5.4.0 program was used to calculate doses to the critical groups using 2011 environmental monitoring data. Where measured environmental data is not available, IMPACT calculates the doses from emissions. IMPACT 5.4.0 represents the method of dose calculation described in the CSA N288.1-08 standard [R-11].

6.2 Calculated Atmospheric Dispersion Factors

Atmospheric dispersion factors (Ka) provide a measure of the dilution of station radiological stack emissions to the atmosphere. Ka values are used to estimate radionuclide concentrations in air at the boundary monitor locations when there are no local measured values available. Details of how and when the Ka values are used are provided in Appendix F, Dose Calculation Procedure and Concentrations.

Factors influencing atmospheric dispersion at a specific location include wind speed and direction, as well as the level of turbulence in the atmosphere.

Ka values are calculated from the measured HTO in air concentrations and station HTO emissions using the relationship:

$Ka = C/Q\ (s/m^3)$

Where C is the annual average HTO in air concentration (Bq/m^3) above background measured outside the station boundary, and Q is the average annual HTO release rate (Bq/s) measured by stack monitors at the point of release. The release rate is determined by dividing the station total annual emission of HTO as given in Table 3-1 by 3.16×10^7 seconds per year.

For the purpose of maintaining a consistent historical comparison, Ka values have been calculated using HTO in air concentrations from the active samplers at the boundary locations. These values are listed in Tables 6-1 and 6-2 for DN and PN, respectively. Figures 6-1 and 6-2 graphically show how these measured Ka values have varied historically at the DN and PN sites.

The boundary average Ka values at both DN and PN show a decrease since 2007. A decrease in Ka values means there is more dilution of emissions released to air. The Ka values obtained from the boundary HTO in air measurements represent a valid year-over-year comparison of air dispersion around DN and PN since the locations are always the same.

Separate Ka values are calculated for the dose calculations based on the measured concentration of HTO in air at each boundary monitor location.

Table 6-1: Darlington Nuclear Annual Boundary Dispersion Factors – 2011

INDICATOR SITES	Measured Average Airborne Tritium Concentration (Bq/m^3)	Measured Ka (s/m^3)
D1 – Southeast Fence	0.7	1.5E-07
D2 – East Fence	0.7	1.4E-07
D3 – Maple Grove	0.4	7.9E-08
D4 – Park Road	0.3	5.8E-08
D5 – Knight Road	0.3	5.3E-08
D6 – Provincial Park	0.2	4.4E-08
Average		**8.8E-08**

NOTE: The measured annual HTO to air emission is used together with the measured levels of HTO in the environment to calculate Ka.

Table 6-2: Pickering Nuclear Annual Boundary Dispersion Factors – 2011

INDICATOR SITES	Measured Average Airborne Tritium Concentration (Bq/m^3)	Measured Ka (s/m^3)
P2 – Montgomery Park Rd.	11.5	6.6E-07
P3 – Sandy Beach Rd.	2.6	1.5E-07
P4 – Liverpool Rd.	1.1	5.9E-08
P6 – East Boundary	4.8	2.7E-07
P7 – Central Maintenance – West	5.0	2.8E-07
P8 – Frenchman's Bay	1.1	6.1E-08
P9 – Petticoat Creek	1.5	8.4E-08
P10 – Central Maintenance –East	9.7	5.5E-07
P11 – Alex Robertson Park	2.4	1.3E-07
Average		**2.5E-07**

NOTE: The measured annual HTO to air emission is used together with the measured levels of HTO in the environment to calculate Ka.

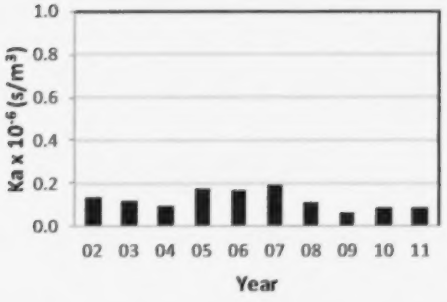

Figure 6-1: Darlington Nuclear Calculated Boundary Average Ka Values

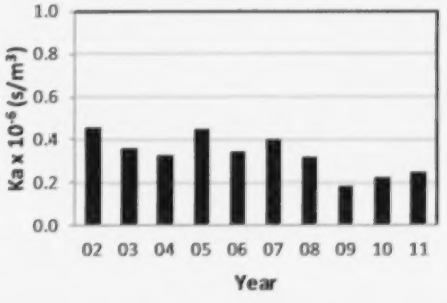

Figure 6-2: Pickering Nuclear Calculated Boundary Average Ka Values

6.3 Meteorological Data

Wind speed, direction and frequency are measured continuously at meteorological towers at each nuclear site. The average annual wind frequencies at a 10 m height in 2011 for the DN and PN sites are presented in Table 6-3 for 16 wind sectors.

The meteorological data are used in the IMPACT program to model radionuclide concentrations at the critical group locations where measured data is not available (such as pathways for I(mfp), Co-60, Cs-137+ and HT). In 2011, the wind sectors from which the wind predominantly blew towards the land were the SW for DN and the SSW for PN. Table 6-3 indicates the wind frequencies blowing from each direction.

Table 6-3: Darlington and Pickering Nuclear – 2011 Annual Average Wind Frequency by Direction (at 10 m height)

Direction Wind Blowing From	Darlington Nuclear Wind Frequency (%)	Pickering Nuclear Wind Frequency (%)
N	10.28	11.04
NNE	3.43	8.12
NE	6.11	3.77
ENE	5.20	4.19
E	7.63	7.05
ESE	3.79	5.80
SE	2.79	3.25
SSE	2.18	1.71
S	1.63	2.05
SSW	3.24	**8.87**
SW	**9.62**	8.25
WSW	6.32	5.72
W	9.01	5.65
WNW	7.70	7.01
NW	12.67	8.86
NNW	8.42	8.65
Total	100.00	100.00

Note: Shaded fields indicate landward wind sectors.

7.0 ASSESSMENT OF DOSES TO THE PUBLIC

This section contains an assessment of doses to the public resulting from the operation of OPG's Nuclear Generating Stations. These doses are based, as much as possible, on environmental concentrations of radionuclides measured at the potential critical group locations and surrounding environment. For the radionuclides and pathways where environmental measurements were not available, dose was modeled from emissions.

In this report, dose to members of the public is calculated only for members of potential critical groups that reside in the vicinity of DN and PN. The calculation follows the method described in OPG's Methodology for Data Analysis and Public Dose Determination for the Radiological Environmental Monitoring Program [R-9]. Assumptions, modeling parameters, and mean intake rates were used in accordance with CSA N288.1-08 [R-11] and the COG DRL Guidance [R-14]. Annual average meteorological data is used along with local intake fractions and representative locations for critical groups, as identified in the reviews of the site-specific surveys [R-1] [R-13] as well as incorporating any recent changes (see 7.1.2). Details on how the data were used are provided in Appendix F.

7.1 Critical Group Dose

The calculation of public dose in this report is intended to be realistic, using the potential critical group lifestyles and attributes collected in the DN and PN site-specific surveys [R-1] [R-10] [R-12] [R-13].

In public dose assessments, "critical groups" are used to estimate the mean realistic impacts of emissions on the most affected individuals. An individual with the average characteristics of the group is known as the "Representative Person" as described in CSA N-288.1-08 [R-11]. A single critical group with the highest total dose estimate is identified for each nuclear site, DN and PN. Since it is not apparent beforehand which group this may be, a number of potential critical groups are identified and dose estimates are calculated for each one. Doses are calculated for three age classes within each potential critical group, adult, child, and infant.

For groups that occupy a relatively small geographic location, radionuclide measurements taken at that location were used in the potential critical group calculations. For groups such as the Farm, Dairy Farm or Urban Resident that are spread over much wider geographic areas, the maximum measured value of each sample type from all group members was used in order to keep the calculated doses conservative.

A small fraction of the adult residents living near PN or DN also work within 5 km of the stations, thereby receiving a different dose while at work and at home. Similarly, a small fraction of the Industrial/Commercial critical group workers live near PN or DN station and continue to receive a dose while at home. As a result, the dose estimates for these critical groups have been adjusted to account for this portion of the population.

7.1.1 Age Classes

In accordance with CSA N-288.1-08, three age classes are used for estimating annual dose to the representative person. The three age classes are 0-5 years (infant), 6-15 years (child), and 16-70 years (adult). The dose estimates to these three age groups are sufficient to characterize doses to the public. For practical implementation in dose calculations, the dose coefficients and characteristics for a one-year old infant, a 10-year old child, and an adult are used to represent the three age classes [R-7].

7.1.2 Darlington Nuclear Potential Critical Groups

The nine potential critical groups at DN for which doses are calculated in this report are shown in Figure C1, Appendix C and are described in Appendix E, Potential Critical Group Descriptions. The critical groups and their representative locations are primarily based on the DN site-specific survey review [R-1] conducted in 2006 and modified, if required, when significant changes are identified prior to the next site-specific survey review cycle. In 2008, the representative location used for modeling the Dairy Farm critical group was relocated to a location approximately 1 km closer to DN, which provides greater conservatism to the modeled air concentrations. Further, a

2009 review of the representative potential critical group locations determined that the Rural Resident and Industrial/Commercial critical group representative locations should be shifted to the west of DN based on updated meteorological data used for atmospheric dispersion and the construction of a new industrial/commercial site.

7.1.3 Pickering Nuclear Potential Critical Groups

The six potential critical groups at PN for which doses are calculated in this report are shown in Figure C2, Appendix C and are described in Appendix E. The potential critical groups and their representative locations are primarily based on the site-specific survey review conducted in 2005 [R-13] and modified, if required, when significant changes are identified prior to the next site-specific review cycle.

7.2 Exposure Pathways

The dose calculations include all pathways of radionuclide uptake or external exposure by humans, as illustrated previously in Section 4.0, Figure 4-1. The dose contribution from each pathway was estimated using IMPACT 5.4.0 either using direct measurements in the environment or by modeling from emissions.

7.3 Critical Group Dose Calculations

Although doses are calculated for several potential critical groups, only the group and age class with the highest dose is reported as the official site public dose in the given year. The following sections provide the basis for the dose calculation, results, and interpretation of the official public dose for DN and PN. Details on the calculations, how the radionuclide concentrations are determined, background subtractions, and whether data is measured or modeled are provided in Appendix F. Tables of doses calculated for all the potential critical groups are provided in Appendix G, Tables of Public Doses by Radionuclide, Pathway and Age Group for Darlington Nuclear and Pickering Nuclear Critical Groups.

7.3.1 Basis of Dose Calculation

- Measurements of HTO and C-14 in fruits, vegetables, silage and milk, and C-14 in air were taken from locations around PN and DN. HTO and noble gases in air were measured at station boundary locations. HTO was measured in WSP drinking water, local well water, and lake water. HTO, C-14 and Cs-137 were measured in fish and Cs-137 was measured in local beach sand. For each potential critical group, the highest annual average concentration of each medium sampled from that group was used for the dose calculation with the background subtracted.

- OBT doses from terrestrial animals and plants were modeled from measured HTO concentrations in terrestrial media.

- Doses from HTO and noble gases in air were estimated based on measurements at the fence line boundary and applying a calculated air dispersion ratio for the critical group location.

- Doses from the remaining radionuclide pathways for I(mfp), Co-60, Cs-137+ and HT, were modeled from emissions applying the Ka dispersion factor as well as the calculated air dispersion ratio for the critical group location (see Section F.2.1)

7.3.2 Darlington Nuclear Public Dose

For 2011, the limiting critical group at DN was Farm adult, with a dose of 0.6 µSv/a, as indicated in Table 7-1.

The Farm critical group represents agricultural farms located within approximately 10 km of the DN site. The representative location of this critical group is the closest farm which is in the WNW wind sector about 2 km from the site. Members of this group obtain their water supply mostly from wells and use it for drinking, bathing, irrigation, and watering livestock. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption from locally grown products.

7.3.2.1 Dose Calculation Results

The results of the 2011 DN public dose calculation are presented in Table 7-1.

Table 7-1: 2011 Darlington Nuclear Critical Group Doses

Potential Critical Group	Dose per Age Class (microsieverts)		
	Adult	Child (10-year old)	Infant (One-year old)
Campers	0.1	0.1	0.1
Dairy Farm Residents	0.5	0.4	0.5
Farm Residents	0.6	0.5	0.3
Sport Fishers	0.1	0.1	0.0
Bowmanville Residents	0.2	0.2	0.1
Oshawa Residents	0.1	0.1	0.0
Rural Residents	0.3	0.3	0.2
West/East Beach Residents	0.2	0.2	0.1
Industrial/Commercial Workers	0.1		

Table 7-2 illustrates the dose from each radionuclide for the Farm adult and percent contribution to the total dose. C-14 and HTO contribute about 90% of the total dose.

Table 7-2: 2011 Darlington Nuclear Public Dose

Radionuclide	Dose (µSv/a)	% Dose Contribution
C-14	2.52E-01	45%
Co-60	9.18E-03	2%
Cs-137+	4.09E-04	0%
HT	4.02E-06	0%
HTO	2.40E-01	42%
Noble Gases	4.69E-02	8%
OBT	1.34E-02	2%
I (mfp)	3.64E-03	1%
Total	5.65E-01	100%

"+" indicates that contributions from progeny are included.

This distribution of dose by radionuclides reflects the characteristics of the Farm group. C-14 dose is mostly from ingestion of terrestrial plants and animal products. A large portion of the animal products, fruits, and vegetables consumed by the Farm group is from local sources. Dose from HTO is attributed to air inhalation and ingestion of local well water, terrestrial plants and animal products.

The public dose trend for DN is presented in Figure 7-1. Hypothetical Individual dose was reported as the site official dose up to and including 2002, and thereafter, the official dose has been based on the site Critical Group and the average member of this critical group has the characteristics of the Representative Person. A description of Hypothetical Individual dose calculation methodology can be found in previously published annual reports.

The DN dose remains essentially unchanged over the last five years and is below 1% of the legal limit.

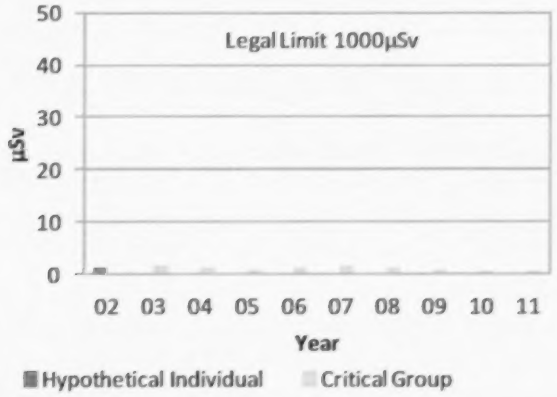

Figure 7-1: Darlington Nuclear Public Dose Trend

7.3.2.2 Discussion of Results

The 2011 DN site public dose of 0.6 µSv, as represented by the Farm adult, is about 0.1% of the 1000 µSv/a legal limit for a member of the public. The DN dose for 2011 is the same as the site public dose of 0.6 µSv for the Dairy Farm infant reported in 2010.

The change in critical group from 2010 represents a very small relative shift in doses between the Farm and Dairy Farm groups, therefore the change in the most affected receptor is not significant.

The DN dose for 2011 is less than 0.1% of the total public background dose. The estimated average background public dose around DN from naturally occurring and anthropogenic (man-made) radiation is about 1,400 µSv/a (excluding medical doses, refer to Section 7.4). Figure 7-2 is a graphical representation of critical group dose compared to background radiation around DN. As an additional source of comparison, Table 7-5 provides examples of typical doses from exposure to natural and anthropogenic sources.

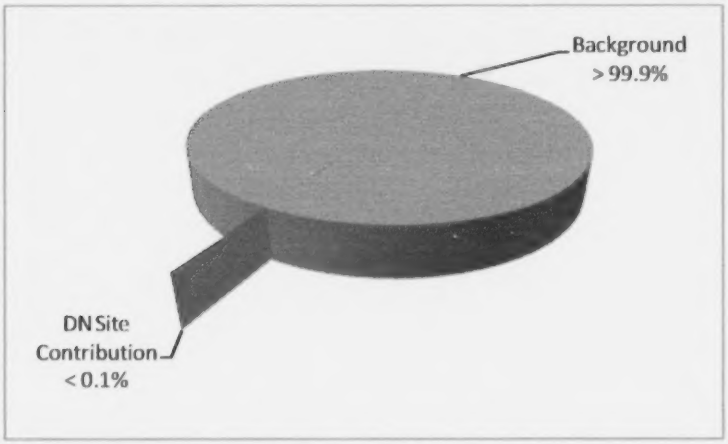

Figure 7-2: Comparison of Darlington Nuclear Public Dose to Background Dose

7.3.3 Pickering Nuclear Public Dose

For 2011, the limiting critical groups at PN were the Urban Resident adult and child, with a dose of 0.9 µSv/a, as indicated in Table 7-3.

The Urban Resident critical group consists of Pickering and Ajax residents in the areas surrounding the PN site. Members of this group drink mostly water from Ajax WSP and also consume a diet comprised in part of locally grown produce and some locally caught fish. Members of this group are also externally exposed to beach sand at local beaches.

A fraction of adult residents within the Urban Resident critical group also work within 5 km of PN station and receive some dose from the station while at work. The average dose for the Urban Resident Adult has been adjusted to account for these residents.

7.3.3.1 Dose Calculation Results

The results of the 2011 PN public dose calculation are presented in Table 7-3.

Table 7-3: 2011 Pickering Nuclear Critical Group Doses

Potential Critical Group	Dose per Age Class (microsieverts)		
	Adult	Child (10-year old)	Infant (One-year old)
Farm Residents	0.3	0.3	0.2
Dairy Farm Residents	0.4	0.3	0.3
Sport Fishers	0.3	0.4	0.3
Urban Residents	0.9	0.9	0.8
C2 Correctional Institution	0.7	0.8	
Industrial Workers	0.8		

Using the averaged values between the Urban Resident adult and 10-year old child, which were very similar, Table 7-4 illustrates the dose from each radionuclide and percent contribution to the total dose. HTO and noble gases contribute more than 90% of the total dose.

Table 7-4: 2011 Pickering Nuclear Public Dose

Radionuclide	Dose (µSv/a)	% Dose Contribution
C-14	1.91E-02	2%
Co-60	3.01E-03	0%
Cs-137+	1.83E-02	2%
HTO	5.18E-01	56%
Noble Gases	3.67E-01	40%
OBT	1.56E-03	0%
I (mfp)	6.82E-05	0%
Total	9.27E-01	100%

"+" indicates that contributions from progeny are included.

This distribution of dose by radionuclides reflects the characteristics of the Urban Resident group since their exposure is mainly from inhalation of HTO and external exposure to noble gases.

The public dose trend for PN is presented in Figure 7-3. Hypothetical Individual dose was reported as the site official dose up to and including 2002, and thereafter, the official dose has been based on the site Critical Group and the average member of this critical group has the characteristics of the Representative Person. A description of Hypothetical Individual dose calculation methodology can be found in previously published annual reports.

The PN dose remains below 1% of the legal limit.

One step change is observed in the PN trend over the last five years. The decrease in 2006 is due to the closure of the correctional institution (C1) and the expropriation of the Squires Beach community for the expansion of the municipal WPCP. These two former potential critical groups were located close to the station and often had the highest doses around the PN site.

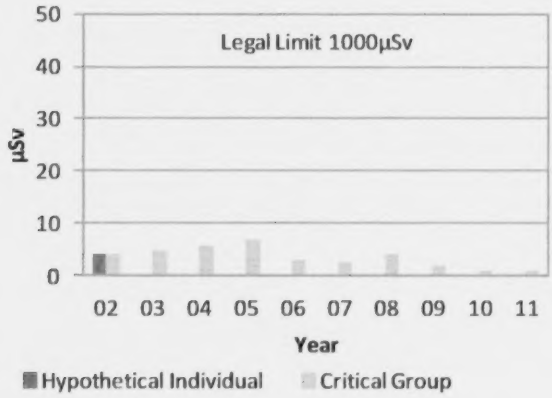

Figure 7-3: Pickering Nuclear Public Dose Trend

7.3.3.2 Discussion of Results

The 2011 PN site public dose of 0.9 µSv, as represented by the Urban Resident adult and child, is 0.1% of the 1000 µSv/a legal limit for a member of the public. The PN dose for 2011 is about the same as the site public dose of 1.0 µSv for the Urban Resident adult reported in 2010.

This small difference is attributed to the reduction in gross beta-gamma emissions to water. This reduction led to a decrease in soil external dose from the reduced Cs-137+ concentrations modeled for soil irrigated by drinking water.

The PN dose for 2011 was equivalent to about 0.1% of the total public background dose. The estimated background dose around PN is 1400 µSv/a from naturally occurring and anthropogenic (man-made) radiation (excluding medical doses, refer to Section 7.4). Figure 7-4 is a graphical representation of critical group dose compared to background radiation around PN.

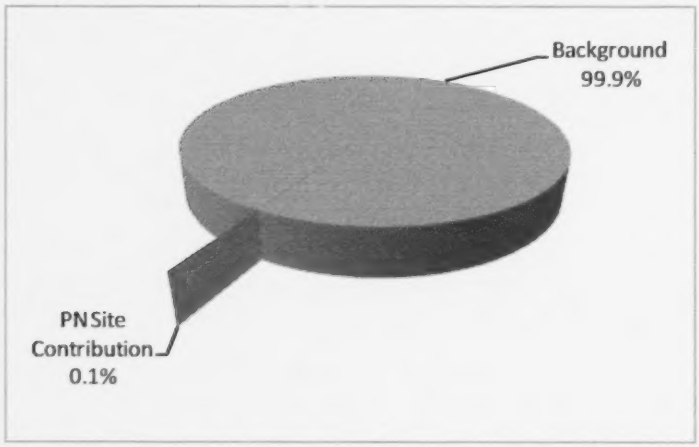

Figure 7-4: Comparison of Pickering Nuclear Public Dose to Background Dose

7.4 Natural and Anthropogenic Dose Data

Table 7-5 provides some typical doses received by members of the public from exposure to natural and anthropogenic sources.

Table 7-5: Typical Doses from Exposure to Natural and Anthropogenic Sources

Source of Exposure	Effective Dose (μSv)
Annual External Exposure during Precipitation Events (Gamma Radiation from Naturally Occurring Radon Gas Decay Products) [R-33]	4
Chest X-Ray (single film) [R-34]	10
Airplane Travel (two hour flight) [R-35]	12

Information on Canadian public doses from naturally occurring sources was updated in 2002, including new data from ground gamma surveys in four major Canadian cities [R-19] [R-20]. Results are summarized in Table 7-6, where it can be seen that most of the variation is due to the inhalation dose from Radon-222 (Rn-222).

Table 7-6: Naturally Occurring Annual Public Effective Doses

Radiation Source	Worldwide Average (μSv)	Canada (μSv)	Toronto (μSv)	Montreal (μSv)	Winnipeg (μSv)	Pickering Nuclear Site (μSv)	Darlington Nuclear Site (μSv)
Cosmic	380	318	313	313	315	313	313
Internal	306	306	306	306	306	306	306
Inhalation[(a)]	1,256	926	757	667	3,225	565	565
External	480	219	178	278	176	154	154
Total[(b)]	**2,400**	**1,800**	**1,600**	**1,600**	**4,000**	**1,300**	**1,300**

(a) Mostly from Rn-222.
(b) Total doses have been rounded to two significant figures to reflect the inherent uncertainty. Some components are based on direct measurements and others are estimated from related measurements.

In addition to naturally occurring radiation, the public also receives about 70 µSv/a effective dose from anthropogenic sources such as nuclear weapon test fallout, and exposures from technological processes and consumer products and services, excluding medical sources. Thus, the total background dose around PN and DN from naturally occurring and anthropogenic sources is 1,400 µSv/a. The average Canadian dose from medical sources averages 1,100 µSv/a per person. The legal limit of 1,000 µSv per year from licensed industrial practices is over and above the dose the public already receives from the natural environment and from medical procedures. [R-21]

8.0 QUALITY ASSURANCE PROGRAM

The Quality Assurance (QA) program for the REMP encompasses all activities in field sample collection, laboratory analysis, laboratory quality control, and external laboratory comparison. The objective is to ensure the accuracy of REMP samples and their analytical results such that best estimates of radiation doses to the public resulting from the operations of OPG Nuclear Generating Stations are provided. This section provides an overview of quality assurance activities that are critical to ensuring the quality of the REMP data.

8.1 Laboratory Quality Assurance and Quality Control

The OPG Health Physics Laboratory (HPL) is accredited for radioanalysis of drinking water and soil by the Canadian Association for Laboratory Accreditation (CALA). The accreditation is based on demonstrated compliance with ISO 17025, General Requirements for the Competence of Testing and Calibration Laboratories. HPL is also licensed for radioanalysis of drinking water by the Province of Ontario's Ministry of Environment. HPL performs laboratory activities in accordance with the OPG Dosimetry and Radiological Environmental Quality Assurance Program [R-22].

8.1.1 Laboratory Quality Control

Quality control (QC) samples are used to estimate the precision and accuracy of analytical results and to examine any sources of error introduced by laboratory practices which require corrective actions. Two types of QC samples are used to accompany the analyses of the environmental samples collected for the REMP:

(a) Process control samples are 'dead water' (radiation-free water/blank) samples that go through the same handling process as the real samples.

(b) QC standards are samples with predetermined values (usually traceable standards) to be included for final analysis. The analysis of the environmental sample is considered valid when the results of the accompanying QC samples are within ± 10-20% of the known/expected values, depending on the analysis type.

For 2011, the results for the QC samples were all within the required range. These results provide added confidence in terms of the quality of data for the program and the consistency of laboratory measurements.

8.1.2 Laboratory Performance Testing

The main purpose of the laboratory performance testing programs is to provide assurance to OPG Nuclear and the CNSC of the laboratory's analytical proficiency (i.e., the accuracy of the measurements). The testing programs provide a quality check to laboratory operations including equipment calibration, analytical procedures, data review and internal QC. These testing programs are a crucial part of the laboratory QA program to demonstrate that the laboratory is performing within the acceptable limits as measured against external unbiased standards.

OPG Nuclear participated in two independent laboratory performance testing programs in 2011 [R-23]. The suppliers of the test samples and irradiations were:

(a) Eckert and Ziegler Analytics Inc.; and
(b) National Research Council of Canada (NRCC).

These programs involved the measurement of tritium, gross beta, and gamma in water/drinking water, gamma emitters in milk and soil, and environmental gamma measurements using TLDs.

(a) Eckert and Ziegler Analytics Inc.

QA test samples are supplied on a quarterly basis by Eckert and Ziegler Analytics Inc. Results of analyses are reported back to Eckert and Ziegler Analytics who then provide performance reports for each of the analytical types. The performance test limits are as follows:

$$-25\% \leq \text{Relative Difference} \leq +50\%$$

$$\text{Relative Precision} \leq 40\%$$

These test limits are adapted from the *in vitro* accuracy specifications of the CNSC's Regulatory Standard S-106 Revision 1, Technical and Quality Assurance Requirements for Dosimetry Services.

All QA performance test results in 2011 met the specified limits. The maximum and minimum Relative Difference and Relative Precision are summarized for each sample type and presented in Table 8-1.

Table 8-1: Summary of Analytics Performance Test Results – 2011

Sample Types	Relative Difference (%)		Relative Precision (%)	
	High	Low	High	Low
Tritium in Water	+1	-6	3	2
Gross Beta in Water	-2	-9	7	4
Gamma in Milk	+10	-12	7	1
Gamma in Water	+22	-8	16	2
Gamma in Soil	+34	-3	6	1

(b) NRCC Environmental Gamma QA Program

The laboratory QA test program for environmental gamma measurements consists of sending 16 Harshaw TLDs on a quarterly basis to the NRCC where they are irradiated to two different levels of exposure.

The Mean Relative Bias is required to be less than ± 30%. The coefficient of variation of the responses is required to be less than 0.35. In addition, the sum of the mean relative bias (as a fraction) and the coefficient of variation is required to be less than 0.50. [R-23]

All testing met performance requirements.

8.2 Audits and Self Assessments

In 2011, Environment Programs Department (EPD) performed two self assessments on different elements of the REMPs. Furthermore, a CALA audit of the HPL was also performed.

A summary of the audits and assessments are provided in the following sections.

8.2.1 Audits

CALA performs audits of accredited laboratories once every two years as a requirement for maintaining accreditation. A CALA audit was performed in 2011 on HPL's involvement in the environmental measurement program. There were no significant findings related to the laboratory's operation.

8.2.2 Self Assessments

(a) Gross Beta and Gamma Laboratory Analysis

Self assessment NO11-000539 was carried out by the EPD to assess procedural compliance and suitability of procedures for environmental gross beta and gamma analysis performed by the HPL. The self assessment determined that these analyses were performed safely and effectively and minor improvements to enhance laboratory procedure clarity were recommended.

(b) Noble Gas Detector Performance

Self assessment NO11-000532 was carried out by the EPD to evaluate the effectiveness of corrective actions implemented in 2009 and 2010 to address issues experienced in 2008 regarding the noble gas detector availability.

The assessment concluded that the corrective actions taken in 2009, which involved hiring a new contractor for detector surveillance and repair, resulted in a substantial increase in detector availability. Subsequently, an agreement was established with Health Canada to maintain and repair the detectors, with OPG providing field support. This arrangement significantly improved detector reliability, reduced the number of field visits for detector maintenance/failures, and eliminated the cost of external contractors to maintain the detectors.

8.3 Third-Party Verification

An independent third-party verification of the annual dose calculations and this report was carried out by Enviro Health Physics Incorporated. Verification was done on the methodology used, assumptions made, input parameter values and data used. This involved checking the dose calculations, IMPACT scenarios, and performing independent replicate IMPACT model runs and hand calculations to validate the results obtained by OPG. Any necessary changes identified by the third-party verification have been addressed and incorporated in this report.

9.0 PROGRAM PERFORMANCE

9.1 Sample Unavailability

A total of 2,350 laboratory analyses were performed for the 2011 REMPs. The analyses covered HTO, gross beta, C-14, I-131, TLD gamma, OBT, and gamma scan. The DN site accounted for 45% of these sample analyses, while the PN and Provincial programs accounted for 40% and 15% respectively. More samples were analyzed for DN than PN because samples are required to represent a greater number of potential critical groups at DN. Of the total analyses performed, 1,144 analyses were used in the dose calculation. Table 9-1 shows the sample types, number of locations, and number of samples used for the dose calculation. It should be noted that Table 9-1 only lists the sample analyses used for dose assessment and does not include all REMP samples.

The unavailability indicator tracks the performance of sample collection and analysis for the REMP. The field sampling campaign of the REMP is designed to collect representative field samples from selected pathways near each nuclear site and from background locations, in order to meet the program objectives as defined in Section 2.0. The sample analyses unavailability percentage is determined by dividing the number of missed or invalid sample analyses by the number of planned sample analyses for each REMP site.

An important objective of the REMP is to estimate the doses to the public based on environmental data measured in the public domain. In accordance with the REMP governing document [R-31], the requirement to meet unavailability limits is specific to the analysis of samples used in the dose calculation. These limits are applied to the PN, DN and provincial REMPs separately.

The unavailability limits for samples used in the dose calculation are provided in Table 9-1 and range from 10-25%. The unavailability limits were derived based on the relative contributions to total dose, therefore higher dose contributors have a lower unavailability limit. The overall unavailability for PN, DN and Provincial REMPs were 4%, 2% and 0%, respectively. For 2011, all unavailability limits were met for individual analyses used in dose calculations.

The 2010 issue with unavailability of provincial background fish samples, due to lack of fish obtained at that location, was resolved in 2011 by collecting Lake Ontario far field fish from a new background location at the Bay of Quinte.

Table 9-1: Unavailability of REMP Sample Data Used for Dose Calculation Purposes

Sample Types	Collection Frequency	Pickering Nuclear				Darlington Nuclear				Provincial Controls				Unavailability Limit
		Locations	Planned Analyses	Actual Analyses	Unavailability	Locations	Planned Analyses	Actual Analyses	Unavailability	Locations	Planned Analyses	Actual Analyses	Unavailability	
Tritium														
Tritium in Air (Molecular Sieve)	Monthly/Quarterly	7	84	83	1%	6	72	72	0%	1	12	12	0%	10%
Water Supply Plants	Weekly Composite	1	48	48	0%	2	96	96	0%					15%
Residential Wells	Monthly	5	60	60	0%	15	177	176	1%					15%
Milk	Monthly Composite	2	24	22	8%	5	60	60	0%					25%
Milk	Quarterly									2	8	8	0%	25%
Lake Water	Monthly [a]	2	23	23	0%	3	28	28	0%					25%
Fruits	Annual	8	8	7	13%	17	17	16	6%					20%
Vegetables	Annual	12	12	10	17%	14	14	12	14%	5	5	5	0%	20%
Animal Silage Feed	Annual	1	1	1	0%	5	5	5	0%					25%
Fish	Annual	1	16	16	0%	2	20	20	0%					25%
Carbon-14														
Carbon-14 in Air	Quarterly	8	32	32	0%	13	50	50	0%	6	24	24	0%	25%
Milk	Monthly Composite	2	24	22	8%	5	60	60	0%					10%
Milk	Quarterly									2	8	8	0%	10%
Fruits	Annual	8	8	7	13%	17	17	16	6%					20%
Vegetables	Annual	12	12	10	17%	14	14	12	14%	5	5	5	0%	20%
Animal Silage Feed	Annual	1	1	1	0%	5	5	5	0%					25%
Fish	Annual	1	16	16	0%	2	20	20	0%	1	16	16	0%	25%
Noble Gases														
External Gamma (Noble Gas Monitors) [b]	Continuous	4	NA	NA	1%	5	NA	NA	1%					25%
Gamma														
Fish	Annual	1	16	16	0%	2	20	20	0%	1	16	16	0%	25%
Beach Sand	Annual	3	3	3	0%	2	3	3	0%	1	2	2	0%	25%
Overall dose sample Unavailability [c]			388	377	4%		678	671	2%		96	96	0%	

Notes: NA = Not Applicable.

(a) For safety considerations, samples are not required during the winter months (Dec. - Mar.).

(b) Noble gas detector unavailability is based on an average of actual run time of all monitors for PN and DN.

(c) Unavailability defined as an average of the percent unavailability of all sample types.

10.0 SUMMARY

10.1 Overall Program Performance

The results of OPG's 2011 REMPs are summarized as follows:

- Overall, the REMPs met their objectives in collecting radiological environmental data for the PN and DN site public dose estimations, for supporting the DRL model and assumptions, and for confirming station emission control.
- No major changes were made to the REMP designs.
- There were no significant deficiencies in sample collection and sample analyses this year. 2,350 environmental data analyses were completed for samples collected around DN and PN sites and at various Ontario background locations. The performance of sample analyses used in the dose calculations was excellent. The overall unavailabilities were 4%, 2%, and 0% for the PN, DN, and Provincial REMPs, respectively.
- An audit and two self assessments were completed this year for the REMPs. No significant adverse findings were identified. Minor improvements were recommended for laboratory procedures.

10.2 Darlington

10.2.1 Summary of Sampling Results

- HTO and C-14 emissions to air and HTO emissions to water remain similar to the previous year. HT emissions to air are slightly higher than the previous year due to increased TRF operation. Boundary noble gas detector dose rates remained below detection limits.
- Annual average tritium concentrations in drinking water from the nearby water supply plants were below 10 Bq/L. HTO and gross beta-gamma activity in well water remained similar to previous years.
- Soil samples had Cs-137 at levels within the range of historic background over the last 10 years and had no detectable Co-60 or Cs-134. There is no indication of buildup of activity in soil.
- Concentrations of HTO and C-14 in air and fish, Cs-137 in fish, and C-14 in milk and vegetation were in line with results seen over the last five years. HTO measured in milk and vegetation were in the lower range of results seen in the last five years.

10.2.2 Summary of Site Public Dose

The 2011 public dose for the DN site was 0.6 µSv and was represented by the adult of the Farm critical group. This dose is the same as the dose of 0.6 µSv reported for the Dairy Farm one-year-old infant in 2010. The site public dose has not changed significantly over the last five years.

10.3 Pickering

10.3.1 Summary of Sampling Results

- HTO emissions to air were similar to the previous year. C-14 emissions to air were lower than the previous year. HTO emissions to water were slightly higher than the previous year due to the units being shut down for the VBO in 2010. There was a significant decrease in gross beta/gamma emissions to water.
- The average dose measured by environmental noble gas monitors at the boundary locations decreased as a result of lower noble gas emissions and frequency of wind blowing towards landward wind sectors.
- Annual average tritium concentrations in drinking water from the nearby water supply plants were below 10 Bq/L. The average HTO activity in well water decreased due to the removal from the REMP of two high HTO concentration wells that are no longer in use as a result of land use change.
- Soil samples had Cs-137 at levels within the range of historic background over the last 10 years and had no detectable Co-60 or Cs-134. There was no indication of a buildup of activity in soil.
- Concentrations of HTO and C-14 in fish, Cs-137 in fish, and C-14 in milk were in line with results seen over the last five years. HTO in milk and C-14 in air were lower than results seen in the last five years. HTO in air, and HTO and C-14 measured in vegetation were similar to 2010.

10.3.2 Summary of Site Public Dose

The 2011 public dose for the PN site was 0.9 µSv and was represented by adult and child members of the Urban Resident group. This dose is similar to the PN 2010 dose of 1.0 µSv for the Urban Resident adult.

11.0 OUTLOOK FOR 2012

11.1 Implementation of CSA N288.4-10

The Canadian Standards Association (CSA) standard Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills, CSA N288.4-10, was issued in 2010 to supersede the 1990 version of the standard. The 1990 version

addressed the protection of humans from nuclear substances. The current version, N288.4-10, expands the scope to include the protection of both humans and the environment from nuclear substances, hazardous substances and physical stressors. This expanded program is called the Environmental Monitoring Program (EMP).

Detailed designs of the DN and PN EMPs to comply with CSA N288.4-10 were developed in 2011. The new EMPs consist of a routine program and one-time supplementary studies. The new designs will be implemented in phases over subsequent years, with the first annual EMP report scheduled for 2014. Phase 1 of the implementation is planned for completion by the end of 2012 in preparation for the 2013 operating year.

As part of phasing in the new EMPs, certain existing routine sampling activities will no longer be needed and will be eliminated starting in the 2012 sampling year. This includes the following:

- TLDs will be discontinued as they are not used for dose assessment because the noble gas detectors provide more accurate, radionuclide-specific results with background dose subtracted.
- Wet/dry fallout sampling will be discontinued as it is not used for dose assessment and is not required in the new EMP designs.
- The current number of sampling locations for provincial background water (17 locations) will be reduced.

In addition, a small number of REMP monitoring stations will be assessed and relocated/installed as necessary to better represent the smaller number of potential critical groups starting in 2013.

12.0 REFERENCES

[R-1] Schweinsberg, S., Review of the Darlington Nuclear Site Specific Survey, OPG Report, NK38-REP-03481-10002-R000, December 20, 2006.

[R-2] Esmaeily, A. to file, Carbon-14 Inventory at OPG Nuclear Sites Calculated for the Radiological Environmental Monitoring Program (REMP), N-CORR-03481-0422006, March 29, 2012.

[R-3] Chase, W.J., Onacea, D., Comparison of OPG's Panasonic and Harshaw Environmental TLD Gamma Monitoring Systems, OPG Report, N-REP-03443.2-10002, March 19, 2007.

[R-4] Health Canada, Environmental Radioactivity in Canada 1989-1996, Radiological Monitoring Report.

[R-5] Antoniazzi, A.B. Results of Inter-comparison of Active and Passive samplers for Monitoring Tritium-in-air in the Environment in the Vicinity of Pickering Nuclear Station, COG Report 06-3059, December 2008.

[R-6] King-Sharp, K.J. and Klukas, M.H., Great Lakes Time-Concentration tritium Model: Using 2008 Tritium Data and Updated Emissions to 2007, COG Report: OP-08-3040, December 2008.

[R-7] ICRP, Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimization of Radiological Protection: Broadening the Process, ICRP Publication 101, Elsevier, 2005.

[R-8] Beninson, D., Gonzalez, A.J., Application of the Dose Limitation System to the Control of ^{14}C Releases from Heavy-Water-Moderated Reactors, IAEA-SM-258/53, 1982.

[R-9] Benovich I., Methodology for Data Analysis and Public Dose Determination for the Radiological Environmental Monitoring Program, N-INS-03481.21-10000, March 21, 2006.

[R-10] Schweinsberg, S., Site-Specific Survey for the Darlington Nuclear Site, OPG Report, NK38-REP-03443-10001-R00, December 14, 2001.

[R-11] Canadian Standards Association, Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities, CAN/CSA-N288.1-08, September 2008.

[R-12] Schweinsberg, S., Site-Specific Survey for the Pickering Nuclear Site, OPG Report, P-REP-03443-10001-R00, December 16, 1999.

[R-13] Schweinsberg, S., Review of Pickering Nuclear Site Specific Survey, OPG Report, P-REP-03481-00001-R001, November 21, 2006.

[R-14] Hart, D., Derived Release Limits Guidance, COG-06-3090-R2-I, November 2008.

[R-15] Canadian Standards Association, Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills, CSA N288.4-10, May 2010.

[R-16] ICRP Publication 74, Conversion Coefficients for use in Radiological Protection Against External Radiation, September 1995.

[R-17] Grasty, R.L., The Air Kerma Rates from the Pickering Nuclear Generating Station, Gamma – Bob Report 00-2, October 2002.

[R-18] Grasty, R.L., Gamma Ray Spectrometric Methods in Uranium Exploranium – Theory and Operational Procedures in Geophysics and Geochemistry in the Search for Metallic Ores; Peter J. Hood, Editor, Geological Survey of Canada, Economic Geology Report 31, pages 147-161, 1979.

[R-19] Grasty, R.L., The Annual Effective Dose from Natural Sources of Ionizing Radiation in Canada, Gamma-Bob Report 02-6, December 2002.

[R-20] Grasty, R.L., LaMarre, J.R., The Annual Effective Dose from Natural Sources of Ionizing Radiation in Canada, Radiation Protection Dosimetry, Volume 108 No. 3, pages 215 to 226, Oxford University Press, 2004.

[R-21] Aldrich, J.E., et al, Radiation Doses from Medical Diagnostic Procedures in Canada, ACRP-9, AECB-INFO-0670, March 1997.

[R-22] OPG, Dosimetry and Radiological Environmental Quality Assurance Program Manual, N-MAN-03416.3-0020, November 19, 2007.

[R-23] Trankovits, S., Annual Summary 2011 – Health Physics Laboratory Environmental Measurement Quality Assurance Program, OPG Report, N-REP-03443.8-10006, March 15, 2012.

[R-24] King, K.J., et al., The Provincial Radiological Environmental Monitoring Program, OPG Report, N-REP-03481-10000-R00, December 14, 2000.

[R-25] OPG letter, Mr. T.N. Mitchell to Mr. T.E. Schaubel and Mr. G.R. Schwartz, "Gross Alpha Maximum Probable Emission Rate Calculations for Airborne Effluents and Closure of the CNSC Action Item No.2005-4-11", N-CORR-00531-04072, December 20, 2007.

[R-26] Borromeo, J., 2007 Results of Radiological Environmental Monitoring Programs, OPG Report , N-REP-03481-10006-R000, April 2008.

[R-27] Brown, A., Pickering Radiological Environmental Monitoring Program (REMP) Review – 2006, OPG Report, P-REP-03481-00002-R000, October 2007.

[R-28] Borromeo, J., Darlington Radiological Environmental Monitoring Program (REMP) Review, OPG Report, NK38-REP-03481-10003-R000, June 2008.

[R-29] Ontario Drinking Water Quality Standards, Safe Drinking Water Act, O. Reg 169/3, 2002.

[R-30] Crouch, M., Validation of OPG Tritium in Air Active Sampler And Assessment of Tritium in Air Passive Sampler Applicability to Environmental Monitoring Program, OPG Report, N-REP-03481.21-10008, March 2010.

[R-31] OPG, Management of the Radiological Environmental Monitoring Programs, N-PROC-OP-0025.

[R-32] International Atomic Energy Agency, "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments" Technical Reports Series No. 472, January 2010.

[R-33] Grasty, R.L., The Annual Effective Dose from Natural Sources of Radiation in the Ground – Pickering Area, Gamma-Bob Report 01-2, 2001.

[R-34] Moeller, D. W., Environmental Health, 3rd Edition, Harvard University Press, 2005.

[R-35] World Health Organization, Cosmic Radiation and Air Travel Information Sheet, November 2005.

[R-36] Cheng, C., 2009 Results of Radiological Environmental Monitoring Programs, N-REP-03481-10008, April 20, 2010.

[R-37] Health Canada, Guidelines for Canadian Drinking Water Quality: Guideline Technical Document, Radiological Parameters, May 2009.

[R-38] Antoniazzi, A.B., Active Tritium-in-Air Sampler – Design Description, COG Report OP-09-3083, July 2010.

Appendix A: Radiological Units and Conversions

Absorbed Dose

1 gray (Gy)	=	1 joule/kg
1 gray (Gy)	=	100 rad
1 milligray (mGy)	=	100 millirad (mrad)

Effective Dose

1 sievert (Sv)	=	100 rem
1 millisievert (mSv)	=	100 millirem (mrem)
1 microsievert (μSv)	=	0.1 millirem (mrem)

Quantity of Radionuclide

1 becquerel (Bq)	=	1 disintegration per second
1 curie (Ci)	=	3.7×10^{10} Bq
1 mCi/(km^2·month)	=	37 Bq/(m^2·month)

Appendix B: Glossary of Acronyms and Symbols

Radionuclides and Units of Measure

Ar-41	Argon-41
Be-7	Beryllium-7
C-14	Carbon-14
CO_2	Carbon Dioxide
Co-60	Cobalt-60
Cs-134	Cesium-134
Cs-137	Cesium-137
Cs-137+	Cesium-137 including progeny
H-3	Tritium (Hydrogen-3)
HT	Elemental Tritium
HTO	Tritium Oxide
I(mfp)	Mixed Fission Products Radioiodines
I-131	Iodine-131
Ir-192	Iridium-192
K-40	Potassium-40
Rn-222	Radon-222
Th	Thorium
U	Uranium
Xe-133	Xenon-133
Xe-135	Xenon-135
µGy	microgray
µSv	microsievert
Bq	becquerel
Bq/kg-C	becquerels per kilogram carbon
Ci	Curie
Gy	Gray
kg	kilogram
L	Litre
mGy	milligray
mSv	millisievert
Sv	Sievert

Acronyms and Abbreviations

BAF	Bioaccumulation Factor
CALA	Canadian Association for Laboratory Accreditation
CANDU	Canada Deuterium Uranium
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
DN	Darlington Nuclear
DRL	Derived Release Limit
dw	Dry weight
E	East wind sector

ECI	Emergency Coolant Injection
ENE	East North East wind sector
EPD	Environment Programs Department
ESE	East South East wind sector
HPL	OPG Health Physics Laboratory
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IMPACT	Integrated Model for Probabilistic Assessment of Contaminant Transport
ISO	International Organization for Standardization
Ka	Atmospheric Dispersion Factor (s/m^3)
Lc	Critical Level
Ld	Limit of Detection
MW	Megawatts
N	North wind sector
NaI	Sodium Iodide
NE	North East wind sector
NNE	North North East wind sector
NNW	North North West wind sector
NRCC	National Research Council of Canada
NW	North West wind sector
OBT	Organically Bound Tritium
OPG	Ontario Power Generation
PN	Pickering Nuclear
PN1-4	Reactors 1 through 4 at the Pickering Nuclear Site
PN5-8	Reactors 5 through 8 at the Pickering Nuclear Site
QA	Quality Assurance
QC	Quality Control
REMP	Radiological Environmental Monitoring Program
S	South wind sector
SE	South East wind sector
SSE	South South East wind sector
SSW	South South West wind sector
SW	South West wind sector
TFWT	Tissue Free Water Tritium
TLD	Thermoluminescent Dosimeter
TRF	Tritium Removal Facility
TWh	Terawatt Hour
W	West wind sector
w.e.	Water Equivalent
WNW	West North West wind sector
WPCP	Water Pollution Control Plant
WSP	Water Supply Plant
WSW	West South West wind sector
WWMF	Western Waste Management Facility

Appendix C: Maps of Environmental Monitoring and Critical Group Locations

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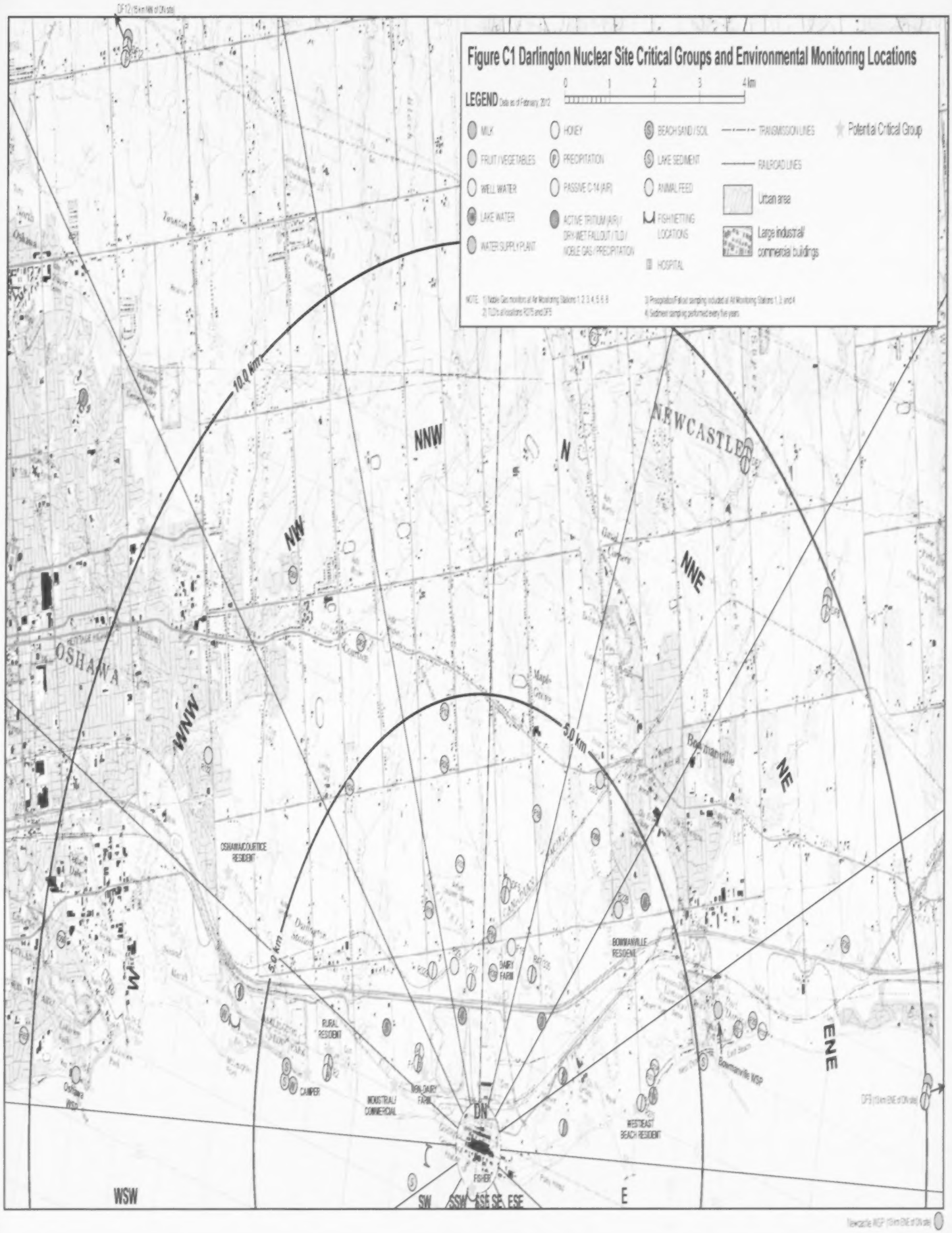


Figure C1 Darlington Nuclear Site Critical Groups and Environmental Monitoring Locations
0 1 2 3 4 km
LEGEND Data as of February 2012
MILK
FRUIT / VEGETABLES
WELL WATER
LAKE WATER
WATER SUPPLY PLANT
HONEY
PRECIPITATION
PASSIVE C-14 (AIR)
ACTIVE TRITIUM (AIR) / DRY-WET FALLOUT / TLD / NOBLE GAS / PRECIPITATION
FISH NETTING LOCATIONS
HOSPITAL
BEACH SAND / SOIL
LAKE SEDIMENT
ANIMAL FEED
TRANSMISSION LINES
RAILROAD LINES
Urban area
Large industrial/ commercial buildings
Potential Critical Group
NOTE: 1) Noble Gas monitors at Air Monitoring Stations 1 2 3 4 5 6 8
2) TLDs at locations R27B and DF5
3) Precipitation/Fallout sampling included at All Monitoring Stations 1, 3, and 4
4) Sediment sampling performed every five years
10.0 km
5.0 km
5.0 km
N
NNW
NW
WNW
NNE
NE
ENE
WSW
SW
SSW
ASE
SE
ESE
E
NEWCASTLE
OSHAWA
Bowmanville
Maple Grove
Darlington Provincial Park
OSHAWA ACOUSTICS RESIDENT
RURAL RESIDENT
CAMPER
INDUSTRIAL / COMMERCIAL
MIX DAIRY FARM
DAIRY FARM
BOWMANVILLE RESIDENT
WESTBEAST BEACH RESIDENT
FISHER
DN
Oshawa WSP
Bowmanville WSP
DF5 (1 km ENE of DN site)
Newcastle WSP (1 km ENE of DN site)

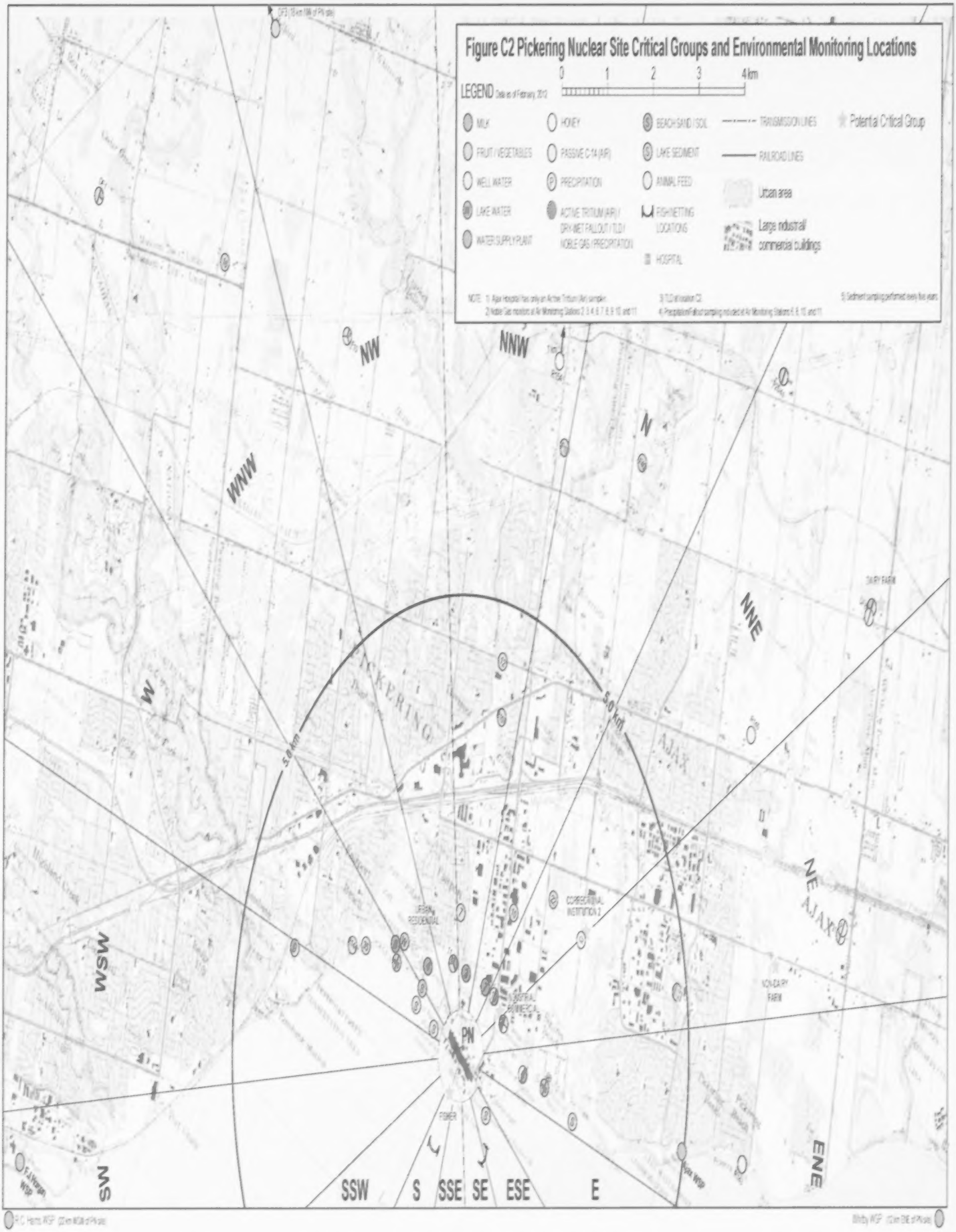
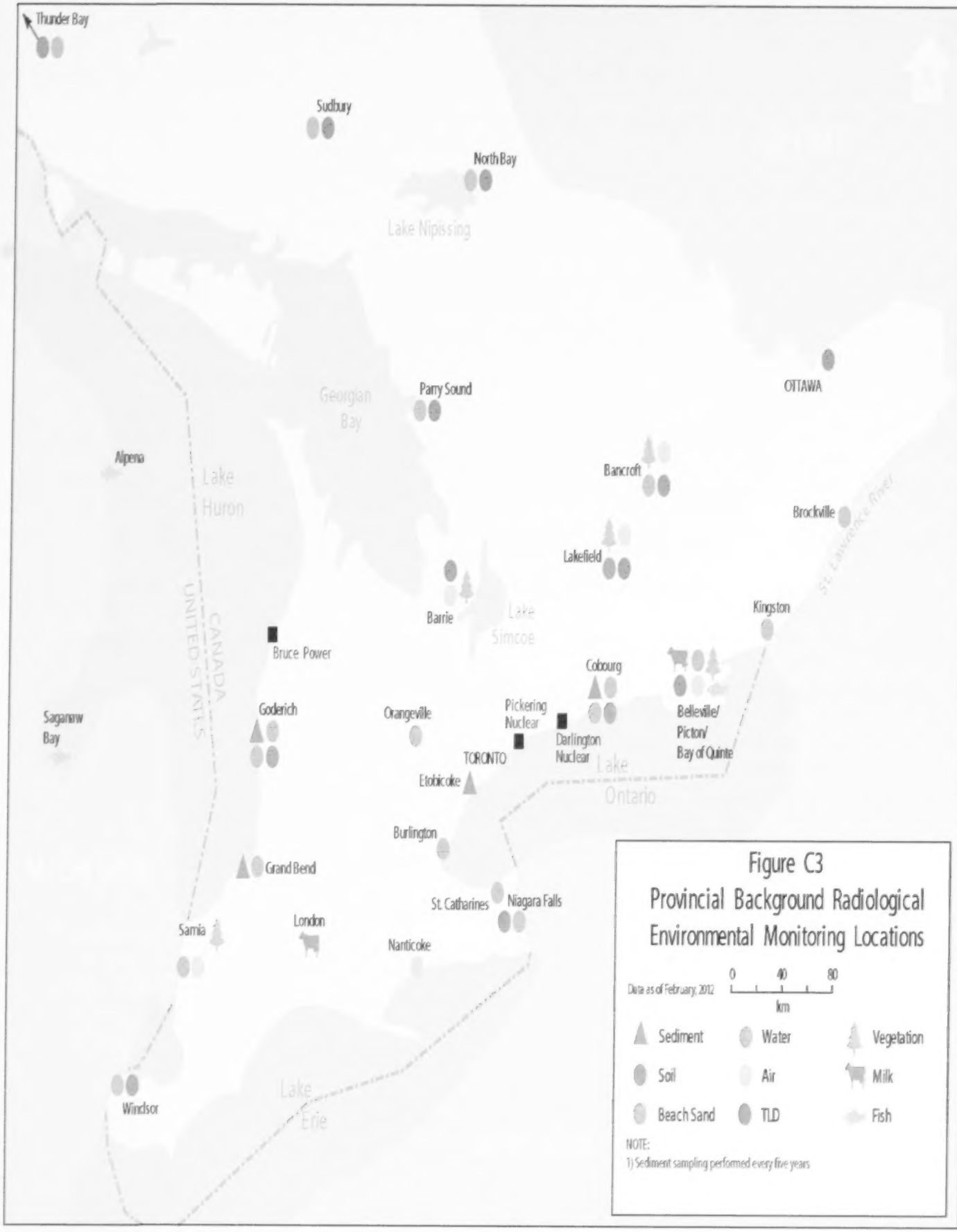


Figure C2 Pickering Nuclear Site Critical Groups and Environmental Monitoring Locations
0 1 2 3 4 km
LEGEND Data as of February, 2012
MILK
FRUIT / VEGETABLES
WELL WATER
LAKE WATER
WATER SUPPLY PLANT
HONEY
PASSIVE C-14 (AIR)
PRECIPITATION
ACTIVE TRITIUM (AIR) / DRY-WET FALLOUT (TLD) / NOBLE GAS / PRECIPITATION
BEACH SAND / SOIL
LAKE SEDIMENT
ANIMAL FEED
FISH NETTING LOCATIONS
HOSPITAL
TRANSMISSION LINES
RAILROAD LINES
Urban area
Large industrial/ commercial buildings
Potential Critical Group
NOTE: 1. Ajax Hospital has only an Active Tritium Air sampler.
2. Noble Gas monitors at Air Monitoring Stations 2, 3, 4, 6, 7, 8, 9, 10, and 11
3. TLD at location C2.
4. Precipitation/Fallout sampling not collected at Air Monitoring Stations 4, 8, 10, and 11
5. Sediment sampling performed every five years.
NW
NNW
N
WNW
W
NNE
WSW
NE
SW
SSW
S
SSE
SE
ESE
E
ENE
5.0 km
5.0 km
PICKERING
AJAX
DAIRY FARM
URBAN RESIDENTIAL
COMMERCIAL/ INSTITUTION 2
HOSPITAL/ COMMERCIAL 8
NON-DAIRY FARM
PN
FISHER
F.J. Horton WSP
Ajax WSP
Whitby WSP


Thunder Bay
Sudbury
North Bay
Lake Nipissing
Georgian Bay
Parry Sound
OTTAWA
Alpena
Lake Huron
Bancroft
Brockville
St. Lawrence River
Lakefield
CANADA
UNITED STATES
Barrie
Lake Simcoe
Kingston
Bruce Power
Cobourg
Saganaw Bay
Goderich
Orangeville
Pickering Nuclear
Darlington Nuclear
Belleville/ Picton/ Bay of Quinte
TORONTO
Etobicoke
Lake Ontario
Burlington
Grand Bend
St. Catharines
Niagara Falls
Samia
London
Nanticoke
Windsor
Lake Erie
Figure C3
Provincial Background Radiological Environmental Monitoring Locations
Date as of February, 2012
0 40 80
km
Sediment
Water
Vegetation
Soil
Air
Milk
Beach Sand
TLD
Fish
NOTE:
1) Sediment sampling performed every five years

Appendix D: Environmental Monitoring Data

Table D1: Tritium-in-Air Concentrations – 2011

DN REMP Locations		PN REMP Locations		Background Locations	
Location	Molecular Sieve Tritium-in-Air (Bq/m^3)[a]	Location	Molecular Sieve Tritium-in-Air (Bq/m^3)[a]	Location	Molecular Sieve Tritium-in-Air (Bq/m^3)[a]
D1	0.7	P10	9.7	Nanticoke	<0.1
D2	0.7	P11	2.4		
D3	0.4	Ajax Hospital	0.7		
D4	0.3	P2	11.5		
D5	0.3	P3	2.7		
D6	0.2	P4	1.1		
D7	**0.2**	P6	4.8		
D8	0.3	P7	5.0		
		P8	1.1		
		P9	1.5		
Boundary Location Average[b]	0.4	Boundary Location Average[b]	4.4	Average	<0.1

NOTES:
Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.
(a) Molecular Sieve Tritium Ld = 0.2 Bq/m^3 and Lc = 0.1 Bq/m^3
(b) DN Boundary Locations: D1, D2, D3, D4, D5, D6. PN Boundary Locations: P2, P3, P4, P6, P7, P8, P9, P10, P11.

Table D2: Carbon-14 in Air Concentrations – 2011

DN REMP Locations		PN REMP Locations		Background Locations	
Location	Passive Sampler C-14 in Air (Bq/kg-C)[a]	Location	Passive Sampler C-14 in Air (Bq/kg-C)[a]	Location	Passive Sampler C-14 in Air (Bq/kg-C)[a]
D1	261	C2	261	Bancroft	232
D2	247	DF1	231	Barrie	244
D6	242	DF8	234	Belleville	259
DF12	236	F31	230	Lakefield	231
DF5	243	P10	407	Lambton	233
DF7	246	P2	428	Picton	232
DF8	224	P6	313		
DF9	241	R145	238		
F1	265				
R2	248				
R27	242				
R275	255				
R329	241				
Boundary Location Average[b]	250	Boundary Location Average[b]	382	Average	238

NOTES:
(a) Bq/kg-C (Bq per kg of carbon). Ld for C-14 = 40 Bq/kg-C.
(b) DN Boundary Locations: D1, D2, D6. PN Boundary Locations: P2,P6, P10.

Table D3: Noble Gas, Skyshine and I-131 Dose in Air – 2011

Boundary Locations	Total Measured Air Kerma Rates (μGy/yr)				
	Ar-41	I-131[(a)]	Ir-192	Xe-133	Xe-135
DN REMP					
D1	*0.042*	*0.017*	**0.025**	**0.003**	**0.008**
D2	*0.039*	*0.018*	**0.027**	*0.004*	**0.009**
D3	**0.037**	**0.019**	**0.030**	**0.005**	**0.010**
D4	**0.035**	**0.016**	**0.026**	**0.004**	**0.009**
D5	**0.034**	**0.016**	**0.029**	**0.004**	**0.009**
D6	**0.038**	**0.014**	**0.025**	**0.003**	**0.009**
D8	**0.040**	**0.015**	**0.027**	**0.004**	**0.009**
Average[(b)]	**0.036**	**0.015**	**0.027**	**0.004**	**0.009**
PN REMP					
P10	2.771	**0.014**	**0.025**	0.064	0.108
P11	0.750	**0.019**	**0.032**	0.012	0.032
P2	1.725	**0.018**	**0.028**	0.044	0.229
P3	0.982	**0.017**	**0.027**	0.022	0.042
P4	0.572	**0.017**	**0.027**	*0.007*	0.028
P6	0.846	**0.019**	**0.031**	0.021	0.129
P7	1.707	*0.017*	**0.026**	0.026	0.068
P8	0.534	**0.015**	**0.026**	0.008	0.026
P9	0.351	**0.014**	**0.028**	*0.007*	0.022
Average[(b)]	1.138	**0.017**	**0.028**	0.024	0.076

Notes:
Italicized values are greater than Lc but less than Ld. Bolded font indicates that the result is less than Lc, and Lc is reported here.
(a) In this context, dose means the air immersion effective dose from gamma radiation.
(b) Annual averages are calculated from monthly measurements and compared with the average Lc or Ld to determine how they will be reported.

Table D4: TLD External Gamma Measurements – 2011

DN REMP Locations		PN REMP Locations		Background Locations	
Location	Annual Dose in Air (μGy/yr)	Location	Annual Dose in Air (μGy/yr)	Location	Annual Dose in Air (μGy/yr)
D1	464	C2	535	Bancroft	547
D2	491	P10	379	Barrie	522
D3	486	P11	514	Belleville	575
D4	455	P2	471	Lakefield	572
D5	448	P3	469	Niagara Falls	414
D6	539	P4	467	North Bay	559
D7	391	P6	560	Ottawa	457
D8	470	P7	410	Parry Sound	473
DF5	532	P8	425	Sudbury	560
R275	515	P9	501	Thunder Bay	547
				Windsor	444
Boundary Location Average[a]	481	Boundary Location Average[a]	466	Average[b]	508

NOTES:
(a) DN Boundary Locations: D1, D2, D3, D4, D5, D6. PN Boundary Locations: P2, P3, P4, P6, P7, P8, P9, P10, P11.
(b) Bancroft and Thunder Bay are excluded from the average due to historically higher than normal levels of natural radioactivity that are inappropriate to be used in comparison with nuclear facility results [R-24].

Table D5: Tritium in Precipitation and Gross Beta in Wet/Dry Fallout – 2011

DN REMP Locations			PN REMP Locations		
Location	Average Tritium Concentration in Precipitation (Bq/L)[a]	Average Gross Beta Deposition Rate (Bq/(m^{2}month))[b]	Location	Average Tritium Concentration in Precipitation (Bq/L)[a]	Average Gross Beta Deposition Rate (Bq/(m^{2}month))[b]
D1	27	16.1	P10	397	14.6
D3	20	16.3	P11	134	17.6
D4	14	19.3	P6	201	16.6
DF12	8	NR	P8	113	25.2
DF8	7	NR	F10	20	NR
F1	25	NR	F31	16	NR
Boundary Location Average[c]	21	17.2	Boundary Location Average[c]	211	18.5

NOTES: NR = Not Required by Program

Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L.

(b) Ld for gross beta = 0.03 Bq/L and Lc = 0.02 Bq/L.

(c) DN Boundary Locations: D1, D3, D4. PN Boundary Locations: P6, P8, P10, P11.

Table D6: Inland Soils and Garden Soils – 2011

Location	Sample Type	Gamma Analysis (Bq/kg dw)[a]					
		Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)
DN REMP							
F1	Soil - Undisturbed	< 0.2	< 0.2	4.0	0.2	676.9	6.9
F16	Soil - Undisturbed	< 0.1	< 0.3	4.1	0.2	624.1	6.8
F16	Soil - Irrigated	< 0.3	< 0.3	4.3	0.3	589.9	9.1
R2	Soil - Irrigated	< 0.2	< 0.3	4.4	0.3	629.9	8.0
R316	Soil - Irrigated	< 0.2	< 0.3	2.8	0.3	681.4	9.6
PN REMP							
P11	Soil - Undisturbed	< 0.1	< 0.3	5.7	0.2	673.4	8.1
P11	Soil - Irrigated	< 0.2	< 0.3	2.9	0.2	58.7	7.2
Background Locations							
Cobourg (A)	Soil - Undisturbed	< 0.2	< 0.3	3.1	0.2	597.4	7.4
Cobourg (B)	Soil - Undisturbed	< 0.1	< 0.2	3.1	0.2	585.6	6.2
Goderich (A)	Soil - Undisturbed	< 0.1	< 0.2	3.1	0.2	373.3	6.1
Goderich (B)	Soil - Undisturbed	< 0.1	< 0.2	3.1	0.2	370.7	5.3
Lakefield (A)	Soil - Undisturbed	< 0.2	< 0.3	5.5	0.2	755.5	6.9
Lakefield (B)	Soil - Undisturbed	< 0.2	< 0.3	6.3	0.3	714.5	9.3

NOTES:

a) For gamma analysis, "<" indicates less than Ld.

Table D7: Terrestrial Biota – 2011

DN REMP Locations					PN REMP Locations							Background Locations						
Location	HTO (Bq/L)[b]		C-14 (Bq/kg-C)[c]		Location	HTO (Bq/L)[b]		C-14 (Bq/kg-C)[c]		OBT (Bq/L (w.e.))		Location	HTO (Bq/L)[c]		C-14 (Bq/kg-C)[c]		OBT (Bq/L (w.e.))	
	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)		Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)		Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)
Fruit[b]					Fruit[b]							Vegetables[b]						
DF12	7.8	2.7	239	22	F10	15.5	3.1	233	21	36	3	Bancroft	4.0	2.0	218	20	23	3
DF7	**3.6**	2.4	235	21	F31	19.0	3.3	243	21	NR	NR	Barrie	4.2	2.0	193	19	19	3
DF9	6.5	2.6	289	24	LOC10	112.1	6.1	301	22	NR	NR	Lakefield	**2.6**	1.9	200	20	10	2
F18	7.5	2.6	258	21	LOC12	38.2	4.0	269	23	NR	NR	Picton	4.6	2.0	216	20	23	3
F26	6.2	2.6	265	22	LOC22	70.5	5.1	291	22	102	5	Sarnia	4.4	2.1	206	20	20	3
R122	13.2	2.9	259	21	LOC35	189.6	7.8	300	22	NR	NR	Average	**3.9**	2.0	208	20	19	3
R19	13.2	3.0	234	20	LOC7	72.1	5.1	263	21	NR	NR							
R2	17.0	3.1	240	21	Vegetables[b]													
R228	21.3	3.3	263	23	DF1	15.4	2.7	232	20	NR	NR							
R24	8.9	2.7	231	21	DF3	11.2	2.5	224	20	NR	NR							
R27	13.2	2.9	288	23	F13	11.5	2.5	232	20	NR	NR							
R275	18.6	3.2	267	22	F40	16.2	2.7	222	20	NR	NR							
R335	13.8	3.0	261	21	F41	14.8	2.6	234	20	28	3							
R35	4.6	2.5	236	20	LOC16	14.5	2.6	241	21	69	4							
R39	13.6	3.0	260	21	P11	112.1	5.8	333	22	NR	NR							
R63	8.6	2.7	254	23	P9	106.2	5.5	286	23	NR	NR							
R85	13.3	3.0	240	20	R144	108.5	5.6	287	23	NR	NR							
Vegetables[b]					R157	20.3	2.9	237	20	NR	NR							
DF2	9.1	2.4	221	20	Average[c]	55.7	4.1	260	21	59	4							
F13	11.4	2.5	251	21	Silage													
F16	18.8	2.9	227	20	DF8	33.1	3.6	210	20	NR	NR							
F25	11.6	2.5	237	20														
R19	9.2	2.4	208	19														
R2	19.3	2.9	228	19														
R228	14.6	2.7	246	20														
R275	7.5	2.3	249	21														
R335	12.1	3.4	226	19														
R356	16.9	2.8	229	19														
R357	9.0	2.4	232	19														
R358	18.6	2.9	229	20														
Average[c]	12.7	2.8	245	21														
Silage																		
DF12	9.2	2.5	240	20														
DF5	34.7	3.6	250	21														
DF7	8.6	2.5	247	20														
DF8	11.4	2.7	236	20														
DF9	**3.3**	2.3	233	21														

NOTES:

NR = Not Required by Program. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C.

(b) Composite vegetables are from the following categories: Above ground (e.g., cucumber, zucchini, tomato, beans and peppers); Below ground (e.g., onion, potato, beet and carrot); Leafy (e.g., chard, cabbage, parsley, sorrel, rhubarb and beet leaves). Two of the three types (i.e., above ground, below ground or leafy) are required to form a valid composite. Typical fruits collected are apples, pears, berries, chestnuts and grapes.

(c) Annual averages for vegetation include fruits and vegetables.

Table D8: Terrestrial Biota (Honey) – 2011

Location	HTO (Bq/L)[b]		C-14 (Bq/kg-C)[b]		Gamma Analysis (wet weight) (Bq/kg)[a]				
	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	K-40 Result	K-40 Uncertainty (±2σ)
DN REMP									
F27	10.9	2.7	227	21	<0.1	<0.1	<0.1	12.7	1.1
R32	40.1	3.8	200	19	<0.1	<0.1	<0.1	25.3	1.5
PN REMP									
R148	23.8	3.2	265	21	<0.1	<0.1	<0.1	17.2	1.6
R154	419.8	11.0	234	20	<0.1	<0.1	<0.1	25.1	2.1

NOTES:
NR = Not Required by Program
(a) For gamma analysis, "<" indicates less than Ld.
(b) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

Table D9: Annual Average Concentrations in Milk – 2011

Location	HTO (Bq/L)[a][b]	C-14 (Bq/kg-C)[a][b]	I-131 (Bq/L)[c]	OBT (Bq/L w.e.)
	Result	Result	Result	Result
DN REMP				
DF12	7.9	238		
DF5	**3.7**	247		
DF7	**2.9**	245		NR
DF8	**4.3**	243		
DF9	**3.3**	238		
Average	**4.4**	242	<0.1	NR
PN REMP				
DF1	13.9	245		NR
DF8	19.1	249		26
Average	16.5	247	<0.1	26
Background Locations				
Belleville	**3.1**	232	<0.1	NR
London	<2.3	241	<0.1	
Average[d]	**2.4**	237	<0.1	NR

NOTES:
NR = Not Required by Program

(a) Weekly samples are used to form monthly composite samples at each farm for HTO and C-14 analysis.

(b) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

(c) For I-131, "<" indicates less than Ld. Weekly samples from all farms are combined to form a weekly composite for I-131 analysis. The annual average I-131 concentration is presented in the table.The background average tritium concentration is calculated from the actual measurements and then compared to the Lc and Ld.

Table D10: Drinking Water and Lake Water – 2011

DN REMP Locations			PN REMP Locations			Background Locations		
Location	Annual Average Gross Beta Activity Concentration (Bq/L)[b]	Annual Average Tritium Concentration (Bq/L)[a]	Location	Annual Average Gross Beta Activity Concentration (Bq/L)[b]	Annual Average Tritium Concentration (Bq/L)[a]	Location	Annual Average Gross Beta Activity Concentration (Bq/L)[b]	Annual Average Tritium Concentration (Bq/L)[a]
WSP			**WSP**			Bancroft	0.05	**3.2**
Bowmanville WSP	0.10	**4.4**	Ajax WSP	0.10	5.8	Belleville	0.08	**3.8**
Newcastle WSP	0.10	4.6	F. J. Horgan WSP	0.11	4.6	Cobourg	0.12	5.6
Oshawa WSP	0.10	5.5	R.C. Harris WSP	0.10	**4.4**	Brockville WSP	0.10	5.1
			Whitby WSP	0.10	5.7	Burlington WSP	0.10	5.0
Well Water			**Well Water**			Goderich WSP	0.10	**4.1**
DF12	0.29	6.0	DF8	NR	13.0	Kingston WSP	0.09	4.6
DF5	0.16	<2.3	F10	NR	10.9	London WSP	0.08	**3.6**
DF7	0.46	<2.3	F25	NR	<2.3	Niagara Falls WSP	0.10	**3.8**
DF8	0.21	**2.4**	F31	NR	17.3	North Bay	0.07	**2.7**
DF9	0.09	<2.3	R143	NR	15.4	Orangeville	0.10	**2.5**
F1	0.07	<2.3				Parry Sound	0.05	**4.1**
F15	0.18	7.7				Sarnia	0.11	**3.7**
R2	2.34	22.4				St. Catherines	0.10	**3.0**
R279	0.02	<2.3				Sudbury	0.03	<2.3
R29	0.08	<2.3				Thunder Bay	0.05	<2.3
R294	0.06	13.9				Windsor	0.08	**4.1**
R316	0.04	10.3						
R320	0.06	8.8						
R329	1.31	13.1						
R47	0.13	10.0						
Lake Water[c]			**Lake Water[c]**					
Darlington Provincial Park	0.12	5.6	Beach Point Promenade	NR	17.3			
McLaughlin Bay	0.21	20.3	Frenchman's Bay	NR	27.4			
West/East Beach	0.17	**4.1**	Squires Beach	NR	16.7			

NOTES:
NR = Not Required by Program
Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.
(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L.
(b) Ld for gross beta = 0.03 Bq/L and Lc = 0.02 Bq/L.
(c) Samples are not required during the winter months.

Table D11: Lake Fish – 2011

DN REMP													
Location	HTO (Bq/L)[a]		C-14 (Bq/kg-C)[a]		Gamma Analysis (wet weight) (Bq/kg)[b]						OBT Composites (Bq/L [water equivalent (w.e.)])	
	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)	Result	Uncertainty (±2σ)
DN Diffuser (Round White Fish) - A	**3.0**	2.3	260	21	<0.1	<0.1	0.2	0.1	134.2	3.3	14	3
- B	5.0	2.4	249	20	<0.1	<0.1	0.2	0.1	134.1	3.0		
- C	**3.8**	2.4	279	21	<0.1	<0.1	0.2	0.1	129.7	3.7		
- D	5.0	2.4	254	21	<0.1	<0.1	0.2	0.1	135.3	3.0		
- E	**4.2**	2.4	251	21	<0.1	<0.1	0.2	0.1	133.1	3.8		
- F	4.6	2.4	231	19	<0.1	<0.1	0.3	0.1	143.9	3.6		
- G	5.0	2.4	224	19	<0.1	<0.1	0.2	0.1	130.1	2.9		
- H	**4.0**	2.4	263	20	<0.1	<0.1	0.2	0.1	136.0	3.0		
DN Diffuser (White Sucker) - A	**4.1**	2.5	277	23	<0.1	<0.1	0.2	0.1	142.5	3.1	26	3
- B	**3.8**	2.5	277	23	<0.1	<0.1	0.2	0.1	139.6	3.0		
- C	**2.8**	2.4	252	21	<0.1	<0.1	0.2	0.1	123.5	2.9		
- D	**3.9**	2.5	259	22	<0.1	<0.1	0.2	0.1	123.4	2.8		
- E	**2.4**	2.4	269	22	<0.1	<0.1	0.2	0.1	127.4	3.3		
- F	**2.4**	2.4	250	20	<0.1	<0.1	<0.1		124.7	2.9		
- G	5.5	2.6	251	20	<0.1	<0.1	0.2	0.1	123.2	3.2		
- H	**2.5**	2.4	233	20	<0.1	<0.1	<0.1		6.0	1.0		
Average	**3.9**	2.4	255	21	<0.1	<0.1	0.2	0.1	124.2	3.0	20	3
McLaughlin Bay - A	22.5	3.3	218	19	<0.1	<0.1	<0.1		102.4	2.6	35	3
- B	23.0	3.3	223	19	<0.1	<0.1	0.1	0.1	67.9	3.3		
- C	23.2	3.3	224	19	<0.1	<0.1	<0.1		97.1	3.2		
- D	20.5	3.2	244	21	<0.1	<0.1	<0.1		104.3	2.7		

NOTES:

(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

(b) For gamma analysis, "<" indicates less than Ld.

Table D11: Lake Fish – 2011 (Continued)

Location	PN REMP											
	HTO (Bq/L)[a]		C-14 (Bq/kg-C)[a]		Gamma Analysis (wet weight) (Bq/kg)[b]						OBT Composites (Bq/L [water equivalent (w.e.)])	
	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)	Result	Uncertainty (±2σ)
Pickering 5-8 Outfall (Round White Fish) -A	10.1	2.7	232	21	<0.1	<0.1	0.3	0.1	128.8	3.3		
- B	17.6	3.0	246	21	<0.1	<0.1	0.2	0.1	138.0	3.4		
- C	9.4	2.6	232	21	<0.1	<0.1	0.1	0.1	132.0	3.8		
- D	7.8	2.5	238	21	<0.1	<0.1	0.1	0.1	121.2	2.8		
- E	10.0	2.7	228	20	<0.1	<0.1	0.2	0.1	129.1	3.0	20	3
- F	11.9	2.8	222	20	<0.1	<0.1	0.3	0.1	120.6	3.6		
- G	12.1	2.8	242	21	<0.1	<0.1	0.2	0.1	116.8	3.6		
- H	12.3	2.8	231	20	<0.1	<0.1	0.2	0.1	130.1	2.9		
Pickering 5-8 Outfall (White Sucker) - A	**3.6**	2.5	262	22	<0.1	<0.1	0.1	0.1	134.4	2.9		
- B	8.6	2.8	268	21	<0.1	<0.1	0.3	0.1	138.5	3.0		
- C	6.9	2.7	270	22	<0.1	<0.1	0.1	0.1	131.4	2.8		
- D	10.1	2.8	255	22	<0.1	<0.1	0.2	0.1	116.8	3.1		
- E	7.1	2.7	237	20	<0.1	<0.1	0.2	0.1	141.8	3.2	17	3
- F	4.6	2.5	253	21	<0.1	<0.1	0.4	0.1	127.7	3.3		
- G	**4.2**	2.5	274	22	<0.1	<0.1	0.2	0.1	121.3	3.6		
- H	6.6	2.6	261	22	<0.1	<0.1	0.1	0.1	105.2	3.4		
Average	8.9	2.7	247	21	<0.1	<0.1	0.2	0.1	127.1	3.2	18.5	2.8

NOTES:
(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.
(b) For gamma analysis, "<" indicates less than Ld.

Table D11: Lake Fish – 2011 (Continued)

Location	HTO (Bq/L)[a]		C-14 (Bq/kg-C)[a]		Gamma Analysis (wet weight) (Bq/kg)[b]						OBT Composites (Bq/L [water equivalent (w.e.)])	
	Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)	Result	Uncertainty (±2σ)
Background Locations												
Lake Ontario (US) Far Field (Round White Fish) - A	5.3	2.1	243	20	<0.1	<0.1	0.2	0.1	144.4	3.1		
- B	5.7	2.1	231	20	<0.1	<0.1	0.3	0.1	136.3	3.8		
- C	**4.1**	2.0	229	20	<0.1	<0.1	0.3	0.1	112.0	3.4		
- D	5.2	2.1	250	20	<0.1	<0.1	0.3	0.1	144.1	3.0	10	3
- E	**4.4**	2.0	221	20	<0.1	<0.1	0.6	0.1	141.9	3.1		
- F	**3.5**	2.0	240	20	<0.1	<0.1	<0.1		143.1	3.9		
- G	5.9	2.1	240	20	<0.1	<0.1	0.4	0.1	130.7	2.9		
- H	**3.4**	2.0	235	21	<0.1	<0.1	0.3	0.1	142.2	3.0		
Lake Ontario (US) Far Field (White Sucker) -A	**4.1**	2.1	197	18	<0.1	<0.1	0.5	0.1	132.9	3.0		
- B	**3.4**	2.1	226	20	<0.1	<0.1	0.3	0.1	118.9	3.6		
- C	**3.5**	2.1	192	17	<0.1	<0.1	<0.1		125.8	3.3		
- D	**2.9**	2.0	194	18	<0.1	<0.1	0.4	0.1	137.5	2.9		
- E	**3.2**	2.1	185	16	<0.1	<0.1	0.4	0.1	111.9	3.1	19	3
- F	4.6	2.2	204	18	<0.1	<0.1	0.5	0.1	132.3	3.8		
- G	**4.1**	2.1	223	20	<0.1	<0.1	0.4	0.1	135.4	3.1		
- H	6.7	2.3	226	19	<0.1	<0.1	0.3	0.1	130.1	2.9		
Average	**4.4**	2.1	221	19	<0.1	<0.1	0.4	0.1	132.5	3.2	14.5	2.6

NOTES:
(a) Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Ld for C-14 = 40 Bq/kg-C. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.
(b) For gamma analysis, "<" indicates less than Ld.

Table D12: Lake Sediment

Location	C-14 Composites (Bq/kg-C)[b]		Gamma Analysis (Bq/kg dw)[a]					
	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)
DN REMP								
Darlington Provincial Park - A	134	27	<0.1	<0.1	0.5	0.1	343.5	4.3
- B			<0.2	<0.2	0.5	0.1	319.5	5.7
- C			<0.1	<0.1	0.4	0.1	351.5	5
- D			<0.2	<0.2	0.5	0.1	354.2	5.1
DN Diffuser - A	193[c]	27	<0.2	<0.1	0.8	0.1	392	6.3
- B			<0.1	<0.1	0.5	0.1	363.8	5.1
- C			<0.2	<0.1	1.3	0.1	472.9	5.6
- D			<0.2	<0.2	0.8	0.2	408.6	6.4
Port Darlington - A	153	28	<0.2	<0.1	0.3	0.1	376.5	5.5
- B			<0.2	<0.2	0.3	0.1	406.1	6.6
- C			<0.2	<0.2	0.3	0.1	399.3	6.6
- D			<0.1	<0.1	0.3	0.1	408.3	5.6
PN REMP								
Duffin's Creek - A	104	26	<0.2	<0.2	0.3	0.2	382	6.3
- B			<0.2	<0.1	<0.2		401.6	5.6
- C			<0.1	<0.2	0.3	0.1	372.6	6.1
- D			<0.2	<0.1	0.3	0.1	385.4	5.3
Liverpool Road Beach - A	195	28	<0.1	<0.1	1.6	0.2	409.7	5.5
- B			<0.2	<0.2	1.8	0.2	411.1	6.5
- C			<0.2	<0.2	1.6	0.2	401	6.5
- D			<0.2	<0.2	1.6	0.2	421.4	5.6
Pickering 1-4 Outfall - A	281[d]	31	<0.1	<0.1	1.4	0.1	396.7	4.8
- B			<0.1	<0.1	1.7	0.1	406.9	5.6
- C			<0.2	<0.2	1.3	0.2	340.1	5.9
- D			<0.1	<0.1	1.4	0.1	383.2	4.7
Pickering 5-8 Outfall - A	204[e]	30	<0.1	<0.2	1.8	0.1	410.5	4.7
- B			<0.1	<0.1	1.3	0.1	377.4	5.3
- C			<0.1	<0.1	1.5	0.1	414	4.9
- D			<0.2	<0.1	1.3	0.2	367.8	6.1
Background Locations								
Cobourg - A	190[f]	27	<0.1	<0.1	0.9	0.1	503.4	5.7
- B			<0.2	<0.1	0.7	0.1	468.5	6.1
- C			<0.2	<0.2	1	0.2	464.6	7.5
- D			<0.2	<0.2	1	0.1	473	6.4
Marie Curtis Park - A	NR	NR	<0.2	<0.1	0.7	0.1	574	6.1
- B			<0.2	<0.2	0.5	0.1	504.3	7.4
- C			<0.1	<0.2	0.6	0.1	528.9	6.7
- D			<0.1	<0.2	0.4	0.1	485.3	5.3

NOTES:
Starting in 2009, the frequency of lake sediment sampling for REMP has been reduced to once every five years. The data presented here is from 2009.

(a) For gamma analysis, "<" indicates less than Ld.
(b) Ld for C-14 = 40 Bq/kg-C.
(c) The total organic carbon content of the DN Diffuser composite sediment samples was 5,100 ppm.
(d) The total organic carbon content of the PN "A" discharge sediment samples was 1,100 ppm.
(e) The total organic carbon content of the PN "B" discharge composite sediment samples was 1,000 ppm.
(f) The total organic carbon content of the Cobourg composite sediment samples was 7,200 ppm.

Table D13: Beach Sand – 2011

Location	Gamma Analysis (Bq/kg dw)[a]					
	Co-60 Result	Cs-134 Result	Cs-137 Result	Cs-137 Uncertainty (±2σ)	K-40 Result	K-40 Uncertainty (±2σ)
DN REMP						
Darlington Provincial Park[b]	< 0.1	< 0.2	0.3	0.1	450.3	5.6
Darlington Provincial Park[b]	< 0.1	< 0.2	0.2	0.1	414.6	4.7
West/East Beach	< 0.1	< 0.2	0.5	0.1	480.9	5.1
PN REMP						
Beach Point Promenade	< 0.1	< 0.2	0.8	0.2	401.7	6.1
Liverpool Road Beach	< 0.1	< 0.2	0.5	0.1	324.5	4.8
Squire Beach	< 0.1	< 0.1	0.9	0.1	482.2	5.0
Background Locations						
Cobourg [A]	< 0.2	< 0.3	0.4	0.1	194.8	4.5
Cobourg [B]	< 0.1	< 0.2	0.4	0.1	207.0	3.9

NOTES:
(a) For gamma analysis, "<" indicates less than Ld.
(b) Darlington Provincial Park samples are for 2nd and 3rd quarters, respectively.

Table D14: Pickering Nuclear Sewage Effluent Results – 2011

Location		HTO (Bq/L)[a]		C-14 (Bq/L)[a]		Gamma Analysis (wet weight) (Bq/kg)[b]				
		Result	Uncertainty (±2σ)	Result	Uncertainty (±2σ)	Co-60 Result	Cs-134 Result	Cs-137 Result	I-131 Result	K-40 Result
PN Sewage Effluent	Quarter 1[c]	3,273	23	<2.3	1.2					
	Quarter 2[c]	2,991	28	<2.3	1.2					
	Quarter 3[c]	2,866	29	<2.3	1.1					
	Quarter 4[c]	3,315	31	<2.3	1.1					
	Annual Average	3,111	28	<2.3	1.2	**0.1**	**0.2**	**0.3**	**0.2**	6.2
Duffin Creek Water Pollution Control Plant Ash[d]	Annual Average	NR				**0.3**	**0.8**	0.8	6.5	256.7

NOTES:
NR = Not Required by Program

(a) Ld for C-14 is 4.5 Bq/L and Lc is 2.3 Bq/L. Ld for tritium = 4.5 Bq/L and Lc = 2.3 Bq/L. Bolded values are greater than Lc but less than Ld. "<"indicates less than Lc.

(b) Annual average of PN Site Sewage Effluent weekly sample results. The sewage stream is treated at the Duffin Creek WPCP. For gamma analysis, bolded font indicates less than Ld.

(c) Quarterly composite samples are prepared from weekly samples.

(d) The ash samples contain elevated concentrations of natural background and medical source radionuclides. The low Cs-137 levels detected are believed to be from atmospheric testing of nuclear weapons from the 1960's.

Appendix E: Potential Critical Group Descriptions

E.1.0 DARLINGTON NUCLEAR POTENTIAL CRITICAL GROUPS

Nine potential critical groups are identified for Darlington Nuclear and are shown in Figure C1 (see Appendix C, Maps of Environmental Monitoring and Critical Group Locations). All of the potential critical groups, with exception of the Industrial/Commercial critical group, consume some locally caught fish near the DN diffuser or in McLaughlin Bay. All critical groups with the exception of the Fisher and Industrial/Commercial critical groups are assumed to be exposed to local beach sand (Darlington Provincial Park). The one-year old infant is assumed to drink cow's milk and water (not infant formula). For all potential critical groups except the dairy farm infant, who drinks fresh local cow's milk, the assumption is made that the milk is a composite from dairy farms all over Ontario which are not affected by station operations.

Based on the site-specific survey review [R-1], a small fraction of residents from the Oshawa/Courtice, Bowmanville, West/East Beach, and Rural Resident potential critical groups work within 5 km of DN. In addition, a small fraction of Industrial/Commercial workers reside close to DN. Therefore, the average Adult doses for these groups have been adjusted to account for the exposure this portion of population receives while at work and at home.

The DN potential critical groups are described as follows:

(a) The **Oshawa/Courtice** potential critical group consists of urban residents in Oshawa and in the community of Courtice within the Municipality of Clarington located to the W and WNW of the site starting at about 6 km from the site. These residents obtain drinking water from the Oshawa WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens.

(b) The **Bowmanville** potential critical group consists of urban residents located to the NE and NNE of the site at distances from 4 to 7 km from DN. These residents obtain drinking water from the Bowmanville WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual meat, poultry and egg consumption from local farms.

(c) The **West/East Beach** potential critical group consists of urban residents located to the ENE of the site at distances from 3.5 km to 7 km. These residents obtain their drinking water from both wells and the Bowmanville WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual poultry and egg consumption from local farms.

(d) The **Farm** potential critical group consists of agricultural farms (but not dairy farms) located in all landward wind sectors around the DN site at distances from

1.5 km to 10 km. The closest is in the WNW wind sector. Members of this group obtain their water supply mostly from wells and use it for drinking, bathing, irrigation and watering livestock. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption from locally grown products.

(e) The **Dairy Farm** potential critical group consists of dairy farms located in all landward wind sectors around the DN site at distances from 3 km to over 10 km. The closest is in the N wind sector. Members of this group obtain their water supply from wells and use it for drinking, bathing, irrigation, and livestock watering. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption, including fresh cow's milk, from locally grown products.

(f) The **Rural Residents** potential critical group consists of residents in rural areas in all landward wind sectors around the site at distances of about 2 km to 5 km. Members of this group obtain about half of their water supply from wells and half from the Bowmanville WSP, and use it for drinking, bathing, and irrigation. They obtain a moderate fraction of their annual fruits, vegetables, poultry and eggs from locally grown products.

(g) The **Industrial/Commercial** potential critical group consists of adult workers whose work location is close to the nuclear site. The closest location for this group is the St. Mary's cement plant about 1.8 km NE of the site, however, the most affected location due to updated meteorological data is the Courtice Water Pollution Control Plant about 2 km W of DN. Members of this group are typically at this location about 23% of the time. They consume water from the Bowmanville WSP.

(h) The **Sport Fisher** potential critical group is comprised of non-commercial individuals fishing near the DN site discharge, about 0.5 km S of the DN site. Members of this group were conservatively assumed to obtain their entire amount of fish for consumption from the vicinity of the DN site and spend 1% of their time at the discharge location where atmospheric exposure occurs.

(i) The **Camper** potential critical group consists of campers at the Darlington Provincial Park, located from 4 to 6 km W of the site at the lakeshore, and includes McLaughlin Bay, a shallow water body where some fishing takes place. The campers are assumed to be in the park no more than six months of the year. They consume drinking water from the Oshawa WSP, and purchase a small fraction of their annual fruits, vegetables, meat, poultry, and eggs from locally grown sources.

E.2.0 PICKERING NUCLEAR POTENTIAL CRITICAL GROUPS

Six potential critical groups are identified for Pickering Nuclear and are shown in Figure C2 (see Appendix C). The one-year old infant is assumed to drink cow's milk and water (not infant formula). For all potential critical groups except the dairy farm infant, who drinks fresh local cow's milk, the assumption is made that the milk is a composite from dairy farms all over Ontario which are not affected by station operations.

Based on the site-specific survey [R-13], a small fraction of Industrial/Commercial workers reside close to PN. Similarly, a fraction of residents from the Urban Resident potential critical group work within 5 km of PN. Therefore, the average Adult doses for these groups have been adjusted to account for the exposure this portion of population receives while at work and at home.

The PN potential critical groups are described as follows.

(a) The **C2** potential critical group consists of inhabitants at a correctional institute, located approximately 3 km NNE of the PN Site. The C2 group obtains drinking water from the Ajax WSP and does not consume locally produced fruits or vegetables. The C2 resident is conservatively assumed to be at this location 100 percent of the time over at least one year.

(b) The **Industrial/Commercial** potential critical group consists of adult workers whose work location is close to the nuclear site. Members of this group are typically at this location about 23% of the time. They consume water from the Ajax WSP. The closest location for this group is about 1 km NNE of the site.

(c) The **Urban Residents** potential critical group consists of Pickering and Ajax area residents which surround the PN Site (e.g., Fairport, Fairport Beach, Rosebank, Liverpool, Pickering Village, etc.). The members of this group mostly consume water from the Ajax WSP and also consume a diet composed in part of locally grown produce and some locally caught fish. Members of this potential critical group are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Liverpool Rd. Beach or Squires Beach).

(d) The **Farm** potential critical group consists of residents of agricultural farms (but not dairy farms) within a 10 km radius of the PN Site. Members of this group obtain most of their water supply from wells but also a portion from the Ajax WSP. Members of this potential critical group consume locally grown produce and animal products, as well as locally caught fish. They are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Liverpool Rd. Beach or Squires Beach).

(e) The **Dairy Farm** potential critical group consists of residents of dairy farms within a 20 km radius of the PN Site. This group obtains most of their water supply from local wells. They also consume locally grown fruit and vegetables and locally

produced animal products, including fresh cow's milk. Members of this potential critical group are also externally exposed to beach sand at local beaches (Beachpoint Promenade, Liverpool Rd. Beach or Squires Beach).

(f) The **Sport Fisher** potential critical group is comprised of non-commercial individuals fishing near the PN site outfalls, 0.5 km S of the PN site. Members of this group were conservatively assumed to obtain their entire amount of fish for consumption from the vicinity of the PN site and spend 1% of their time at the outfall location where atmospheric exposure occurs.

Appendix F: Dose Calculation Procedure and Concentrations

F.1.0 CRITICAL GROUP DOSE CALCULATION PROCEDURE

The dose calculations were performed according to N-INS-03481.21-10000, Methodology for Data Analysis and Public Dose Determination for the Radiological Environmental Monitoring Program [R-9]. Where there was a deviation from this methodology that deviation is listed below, however the methodology used is consistent with CSA N288.1-08 [R-11] and software used for dose calculation, IMPACT 5.4.0, is also compliant with CSA N288.1-08:

- An update to N288.1-08 was issued in 2011. Only one change in this update affects the dose calculation and it is related to the parameters used for beef cows consuming dry feed. Since using the existing parameters produces a conservative dose estimate, this change has not yet been applied and will be incorporated for future dose assessments.

- OBT doses from terrestrial animals and terrestrial plants were modeled using HTO concentrations measured in terrestrial samples at the critical groups. OBT doses from fish were modeled from HTO concentrations in fish.

- HTO and C-14 concentrations in terrestrial animal products other than milk are modeled from measured concentrations of HTO and C-14 in animal feed, forage, air and water. The concentrations are used to calculate the dose from ingestion of animal products. The dose resulting from I(mfp) and particulate is modeled from emissions and empirical Ka values and the ratio of modeled Ka values for the boundary monitor location and the critical group location.

- Location specific measures of each radionuclide were used in the potential critical group calculations where the group occupied a relatively small geographic location. Some groups such as the Farm, Dairy Farm or Urban Resident are spread over much wider geographic areas, and for these the maximum value of all measurements for members of the group was used in order to keep the calculated doses conservative.

- Only dairy farm residents ingest local cow's milk.

- People are generally assumed to be at the critical group location 100% of the time, with the exception of the Industrial/Commercial workers and the Fisher groups. Details are provided in Appendix E. Based on the site specific surveys, a small fraction of residential critical group members at both PN and DN work within 5 km of the station. In addition, a small fraction of Industrial/Commercial workers reside close to the station at both PN and DN. Therefore, the average Adult doses for these groups have been adjusted at both PN and DN to account for the exposure this portion of the population receives while at work and at home.

- No local grain products are consumed by humans.
- The Fisher critical group is located offshore and it is impractical to measure radionuclide concentrations in the air at that location. Therefore, air concentrations are modeled from emissions for this critical group location, while fish concentrations are measured.
- Dose calculation parameters align with CSA N288.1-08

F.2.0 CRITICAL GROUP RADIONUCLIDE CONCENTRATIONS AND BACKGROUND SUBTRACTIONS

The following section details how the radionuclide concentrations are determined, whether they are measured or modeled, and any calculations made to obtain results.

A summary on the radionuclides and pathways measured and modeled in the critical group dose calculation is presented in Table F1. DRL Guidance document [R-14] provides a description of each pathway.

Table F1: Radionuclide and Pathway Data Used in the Critical Group Dose Calculation

Pathway	Radionuclide	Modeled[1]	Measured
Air Inhalation	HTO	✓(Fisher)	✓
	HT	✓[2]	
	C-14	✓[2]	✓
	I(mfp)	✓[2]	
	Co-60	✓[2]	
Air External Exposure	Noble Gas		✓[3]
	C-14	✓[2]	✓
	I(mfp)	✓[2]	
	Co-60	✓[2]	
Soil External Exposure	C-14	✓	
	I(mfp)	✓	
	Cs-137+, Co-60	✓	
Sand External Exposure	C-14	✓	
	I(mfp)	✓	
	Cs-137+		✓
Water External Exposure (Lakes, WSPs, Wells)	HTO	✓(wells)	✓
	C-14	✓	
	I(mfp)	✓	
	Cs-137+	✓	
Terrestrial Animals Ingestion	HTO	✓	✓(milk)
	C-14	✓	✓(milk)
	I(mfp)	✓	
	Cs-137+, Co-60	✓	
	OBT	✓[4]	
Terrestrial Plants Ingestion	HTO		✓
	C-14		✓
	I(mfp)	✓	
	Cs-137+, Co-60	✓	
	OBT	✓[4]	
Aquatic Animals Ingestion	HTO		✓
	C-14		✓
	I(mfp)	✓	
	Cs-137+		✓
	OBT	✓[4]	
Sand and Soil Incidental Ingestion	HTO	✓	
	C-14	✓	
	I(mfp)	✓	
	Cs-137+, Co-60	✓	✓(sand)
Water Ingestion (WSPs, Wells)	HTO		✓
	C-14	✓	
	I(mfp)	✓	
	Cs-137+	✓	

"+" indicates that contributions from progeny are included.

(1) Modeling is based on emissions or from local air measurements where they are available.
(2) Concentrations are modeled from emissions and adjusted using empirical Ka determined for each critical group location.
(3) Doses are measured directly at the site boundary and adjusted to critical group locations using the ratio of modeled air dispersion factors for the boundary monitor and critical group.
(4) OBT dose is modeled from HTO concentration in terrestrial plants, terrestrial animals, or fish respectively.

F.2.1 Tritium

For the purpose of estimating the critical group dose, the concentrations used in the corresponding pathways were determined as follows:

(a) **Air** – Tritium-in-air is measured at boundary locations with measured background tritium-in-air subtracted, and these values are used to estimate concentrations at each critical group location using the ratio of modeled atmospheric dispersion factors for the boundary monitor location and the critical group location (except for the Fisher critical group where it is modeled from emissions).

Concentrations of radionuclides in air that are not minitored at boundary sites or critical groups are obtained for the critical group location as follows:

The concentrations at the boundary monitor sites are estimated using their emissions data and empirical Ka values obtained from HTO emissions and HTO boundary monitor measurements. The concentrations at critical group locations are modeled from the empirically estimated boundary location concentration by using the ratio of modeled air dispersion factors for the boundary monitor location and the critical group location.

(b) **Water** – Drinking water is sampled and measured at the local WSPs and also at wells where local residents obtain their water. For the WSPs, the annual average concentration is used with background tritium concentration subtracted. The background tritium concentration is calculated for natural and weapons fallout contributions using the Great Lakes Time-Concentration Tritium Model [R-6]. For wells, the maximum annual average concentration found at each critical group is used and background is assumed to be zero. Tritium concentration in wells used for purposes other than drinking water is modeled. Lake water HTO concentrations are measured monthly and used to calculate the dose from water immersion. Background HTO concentrations from the Great Lakes Time-Concentration Tritium model [R-6], are subtracted.

(c) **Milk** – Milk from local dairy farms is sampled on a weekly basis and a monthly composite is analyzed. The highest annual average of all the dairy farms is used for the dose calculation, with background tritium in milk concentration subtracted. Only dairy farm residents drink local milk since it is illegal to sell unprocessed milk.

(d) **Fruits and Vegetables** – Fruit and vegetable tritium concentrations are measured at each critical group location and the background tritium concentration is subtracted. The maximum concentration measured from all samples measured for each critical group is used in the dose calculation.

(e) **Silage** – Silage is a dry animal feed (e.g. hay, corn) used at farms and dairy farms and is usually harvested from the previous year. In Pickering, one silage sample is obtained from a Dairy Farm around the site. Since the Farms and the

Dairy Farms are located at a fair distance away from the nuclear station (>8 km) it is assumed that there is not a large difference in radionuclide concentrations in silage obtained at these locations. Therefore, a silage sample taken at one location is applied to both the Farm and Dairy Farm critical groups. Background values are subtracted. At Darlington, silage samples are obtained from Dairy Farms. The maximum value is used for the Dairy Farm critical group. However this value cannot be used for the Farm critical group because it is located much closer to DN, therefore radionuclide concentrations in silage for the DN Farm is modeled from concentrations in air.

(f) **Forage** – Forage includes plants consumed by animals during pasture or in the wild. Where possible, measured HTO and C-14 in vegetable concentrations were used to represent forage in the dose model. For critical groups with forage as a dose pathway but for which vegetable samples are not collected (i.e. DN Camper), forage is modeled from radionuclide concentrations in air.

(g) **Fish** – The radionuclide concentrations used for locally caught fish are the maximum measured values in the fish samples, minus the background tritium in water concentration, as calculated using the Great Lakes Time-Concentration Tritium Model [R-6].

F.2.2 Carbon-14

For the purpose of estimating the critical group dose, the concentrations used in the corresponding pathways were determined as follows:

(a) **Air** – C-14 via air inhalation is not a significant contributor to public dose and, therefore, is only monitored at select high frequency wind sector locations. Where C-14 in air measurements are available, the concentration of C-14 in air is based on the annual average of measurements for each critical group location. If more than one sample location is used to represent one critical group, then the maximum of the annual averages is taken. Where C-14 in air measurements are not available (PN Urban Residents, DN Oshawa Residents and DN Bowmanville Residents), C-14 in air is modeled from emissions and adjusted using the empirical Ka as described in Section 6.2. For all measurements, the average background C-14 concentration in air is subtracted.

(b) **Water** – Concentrations of C-14 in well water are modeled from measured local air concentrations at each critical group location, and concentrations in the WSPs and lake water are modeled from site waterborne emissions.

(c) **Terrestrial media** – The concentrations of C-14 in terrestrial media (plants, milk, hay) are based on the maximum of the measurements for each sample type for each critical group, minus the average C-14 concentration measured in background vegetables.

(d) **Fish** – For fish, the maximum C-14 concentration of all samples per site is used, minus the average concentration of C-14 in Lake Ontario fish measured in background locations.

F.2.3 Noble Gases and Skyshine

The noble gas detectors measure the air kerma rate, which is converted to effective dose using appropriate age-specific conversion factors (effective dose/air kerma rate) [R-16] and standard occupancy and shielding factors for air immersion dose as described in CSA N288.1-08 [R11].

Noble gas dose is measured directly in most landward wind sectors around the DN site and PN site boundaries, and adjusted to the critical group location using calculated air dispersion ratios.

The air kerma rate from the PWMF at the PN site was measured in September 2000 over water on Lake Ontario [R-17]. The results showed a rapid drop in the measured air kerma rate with distance, such that it is below the detection limit (0.13 nGy/h) at a distance of 500 m from these storage areas. At 1 km distance, the air kerma rate is estimated to be negligible assuming an inverse square relation with distance as well as a further reduction of a factor of 1,000 due to scattering in air (effective half distance of 56 m for skyshine radiation at 300 keV [R-18]). The skyshine dose from this source is, therefore, not significant for critical groups outside the 1 km boundary, which are all the critical groups except the Fisher which is assumed to be located 500 m south of PN in Lake Ontario. Skyshine doses from the PWMF and PN station are estimated and included in the total noble gas dose for all critical groups.

Similarly, skyshine doses at DN are estimated and included in the critical group noble gas doses. Skyshine doses are found to be negligible for all critical groups.

F.2.4 Radioiodines

Radioiodine emissions are assumed to have an equilibrium mixture of radioiodines based on I(mfp). This is to account for short-lived radioiodines which may be emitted along with I-131. Emissions for each short-lived radioiodine are incorporated into the dose model based on its equilibrium ratio to the measured I-131 emission. Doses are modeled for the individual radioiodines and summed for the total I(mfp) dose. Due to the very short half-lives of some of these radioiodines, this calculation may overestimate the doses.

Radioiodines are an airborne emission, therefore radioiodine concentrations at critical group locations are obtained as described in Section F.2.1. Where no empirical Ka values are available, air concentrations are directly modeled from emissions.

F.2.5 Particulates and Gross-Beta Gamma

Both airborne particulates and waterborne gross-beta emissions represent a mixture of beta and gamma emitting radionuclides. In order to obtain conservative doses for

these mixtures, they are represented by the most limiting radionuclides typically found in the mixtures. According to the latest REMP reviews [R-27][R-28], the most limiting radionuclide for atmospheric particulate emissions is Co-60 and for liquid effluent beta-gamma emissions it is Cs-137. There was no analysis for alpha radioactivity because alpha radionuclide emissions from the stations are extremely low [R-25].

For airborne particulates, concentrations in air are modeled using emissions, the empirical Ka at each critical group location and modeled atmospheric dispersion factors, as described in Section F.2.1, and concentrations in terrestrial media are subsequently modeled from the airborne concentrations. These concentrations are used to calculate doses to critical group individuals.

For waterborne gross-beta gamma, critical group doses are directly modeled from emissions in aquatic media where no local measurements are available. The only pathways used for dose calculation in which gross beta-gamma activity is measured in environmental samples are fish and beach sand. Background values of activity in Lake Ontario fish and beach sand are subtracted from these measurements.

F.2.6 Elemental Tritium

For HT, the inhalation pathway is the only direct pathway to humans resulting in dose. Concentrations in air are modeled using emissions, the empirical Ka at each critical group location and modeled atmospheric dispersion factors, as described in Section F.2.1. HT converts into HTO through interaction with microbes in the soil. The resultant HTO is routinely measured in air and local biota around nuclear sites.

Appendix G: Tables of Public Doses by Radionuclide, Pathway and Age Group for Darlington Nuclear and Pickering Nuclear Critical Groups

Table G1: Darlington Nuclear – Farm Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C 14	uSv/a	3.75E 04	4.32E 07	5.85E 06	7.78E 11	0.00E+00	0.00E+00	1.50E 10	9.60E 12	0.00E+00	9.81E 04	1.45E 01	1.05E 01	2.52E 01
	Co 60	uSv/a	9.03E 06	3.42E 07	1.96E 07	2.66E 08	8.74E 09	9.06E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E 04	3.60E 06	9.18E 03
	Cs 137	uSv/a	0.00E+00	0.00E+00	3.33E 05	4.68E 06	0.00E+00	0.00E+00	7.31E 07	3.71E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.09E 04
	HT	uSv/a	4.02E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.02E 06
	HTO	uSv/a	9.85E 02	0.00E+00	9.92E 02	2.52E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E 05	2.67E 02	1.33E 02	2.40E 01
	NobleGases	uSv/a	0.00E+00	4.69E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.69E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.05E 06	4.15E 03	9.24E 03	1.34E 02
	I (mfp)	uSv/a	1.02E 04	8.06E 06	8.47E 07	4.43E 09	5.27E 10	2.32E 05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E 03	8.55E 04	3.64E 03
	Total	uSv/a	9.90E 02	4.69E 02	9.92E 02	2.53E 03	9.27E 09	9.09E 03	7.31E 07	3.71E 04	0.00E+00	1.00E 03	1.79E 01	1.29E 01	5.65E 01
Child 10y	C 14	uSv/a	5.36E 04	4.32E 07	4.15E 06	7.78E 11	0.00E+00	0.00E+00	8.29E 10	9.60E 12	0.00E+00	5.80E 04	1.07E 01	6.49E 02	1.73E 01
	Co 60	uSv/a	1.29E 05	3.42E 07	3.26E 07	2.66E 08	1.13E 07	9.06E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E 04	6.47E 06	9.25E 03
	Cs 137	uSv/a	0.00E+00	0.00E+00	1.32E 05	4.68E 06	0.00E+00	0.00E+00	2.25E 06	3.71E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.91E 04
	HT	uSv/a	4.78E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.78E 06
	HTO	uSv/a	1.17E 01	0.00E+00	6.37E 02	2.10E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.54E 06	1.79E 02	7.37E 03	2.08E 01
	NobleGases	uSv/a	0.00E+00	4.69E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.69E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.55E 06	3.17E 03	5.50E 03	8.67E 03
	I (mfp)	uSv/a	2.32E 04	8.06E 06	1.03E 06	4.43E 09	4.98E 09	2.32E 05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.12E 03	1.39E 03	4.77E 03
	Total	uSv/a	1.18E 01	4.69E 02	6.38E 02	2.11E 03	1.18E 07	9.09E 03	2.25E 06	3.71E 04	0.00E+00	5.91E 04	1.32E 01	7.92E 02	4.52E 01
Infant_1y	C 14	uSv/a	3.66E 04	4.32E 07	0.00E+00	2.63E 11	0.00E+00	0.00E+00	1.66E 09	9.60E 12	0.00E+00	3.41E 04	9.95E 02	5.27E 02	1.53E 01
	Co 60	uSv/a	9.44E 06	4.45E 07	0.00E+00	3.45E 08	2.78E 07	1.18E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E 04	9.83E 06	1.20E 02
	Cs 137	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.70E 06	4.82E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E 04
	HT	uSv/a	3.27E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.27E 06
	HTO	uSv/a	8.03E 02	0.00E+00	0.00E+00	6.73E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.71E 06	1.63E 02	6.56E 03	1.04E 01
	NobleGases	uSv/a	0.00E+00	5.75E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.75E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E 06	2.69E 03	4.51E 03	7.20E 03
	I (mfp)	uSv/a	2.71E 04	1.05E 05	0.00E+00	5.76E 09	1.74E 08	3.02E 05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.33E 03	3.90E 03	8.54E 03
	Total	uSv/a	8.09E 02	5.75E 02	0.00E+00	6.73E 04	2.95E 07	1.18E 02	2.70E 06	4.82E 04	0.00E+00	3.48E 04	1.23E 01	6.77E 02	3.42E 01

Table G2: Darlington Nuclear – Dairy Farm Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C 14	uSv/a	1.07E 04	1.23E 07	2.47E 06	3.27E 11	0.00E+00	0.00E+00	1.50E 10	9.60E 12	0.00E+00	1.95E 04	6.15E 02	3.43E 01	4.05E 01
	Co 60	uSv/a	1.83E 06	6.95E 08	0.00E+00	0.00E+00	9.30E 10	9.64E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E 05	4.45E 06	1.01E 03
	Cs 137	uSv/a	0.00E+00	0.00E+00	0.00E+00	4.68E 06	0.00E+00	0.00E+00	7.31E 07	3.71E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.76E 04
	HT	uSv/a	8.16E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.16E 07
	HTO	uSv/a	2.00E 02	0.00E+00	6.10E 02	1.98E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.80E 06	1.12E 02	2.09E 02	1.15E 01
	NobleGases	uSv/a	0.00E+00	7.76E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.76E 03
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E 06	1.75E 03	5.69E 03	7.44E 03
	I (mfp)	uSv/a	2.09E 05	1.57E 06	0.00E+00	0.00E+00	1.04E 10	4.64E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E 03	1.38E 03	2.41E 03
	Total	uSv/a	2.01E 02	7.76E 03	6.10E 02	1.98E 03	1.03E 09	9.69E 04	7.31E 07	3.71E 04	0.00E+00	1.99E 04	7.54E 02	3.71E 01	5.39E 01
Child 10y	C 14	uSv/a	1.53E 04	1.23E 07	1.75E 06	3.27E 11	0.00E+00	0.00E+00	8.29E 10	9.60E 12	0.00E+00	1.15E 04	4.55E 02	2.72E 01	3.18E 01
	Co 60	uSv/a	2.62E 06	6.95E 08	0.00E+00	0.00E+00	1.20E 08	9.64E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.99E 05	1.37E 05	1.04E 03
	Cs 137	uSv/a	0.00E+00	0.00E+00	0.00E+00	4.68E 06	0.00E+00	0.00E+00	2.25E 06	3.71E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E 04
	HT	uSv/a	9.70E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.70E 07
	HTO	uSv/a	2.38E 02	0.00E+00	3.92E 02	1.65E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E 06	7.45E 03	2.54E 02	9.75E 02
	NobleGases	uSv/a	0.00E+00	7.76E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.76E 03
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.05E 07	1.33E 03	5.50E 03	6.83E 03
	I (mfp)	uSv/a	4.74E 05	1.57E 06	0.00E+00	0.00E+00	9.86E 10	4.64E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E 03	3.21E 03	4.45E 03
	Total	uSv/a	2.40E 02	7.76E 03	3.92E 02	1.65E 03	1.30E 08	9.69E 04	2.25E 06	3.71E 04	0.00E+00	1.17E 04	5.55E 02	3.06E 01	4.36E 01
Infant 1y	C 14	uSv/a	1.04E 04	1.23E 07	0.00E+00	7.42E 12	0.00E+00	0.00E+00	1.66E 09	9.60E 12	0.00E+00	6.79E 05	4.25E 02	3.68E 01	4.10E 01
	Co 60	uSv/a	1.92E 06	9.03E 08	0.00E+00	0.00E+00	2.96E 08	1.25E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.82E 05	3.44E 05	1.35E 03
	Cs 137	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.70E 06	4.82E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E 04
	HT	uSv/a	6.65E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.65E 07
	HTO	uSv/a	1.63E 02	0.00E+00	0.00E+00	3.35E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.36E 07	6.67E 03	5.90E 02	8.24E 02
	NobleGases	uSv/a	0.00E+00	9.52E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E 03
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.28E 07	1.11E 03	1.01E 02	1.12E 02
	I (mfp)	uSv/a	5.54E 05	2.05E 06	0.00E+00	0.00E+00	3.45E 09	6.03E 06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.64E 03	1.12E 02	1.29E 02
	Total	uSv/a	1.65E 02	9.53E 03	0.00E+00	3.35E 04	3.30E 08	1.26E 03	2.70E 06	4.82E 04	0.00E+00	6.92E 05	5.19E 02	4.48E 01	5.28E 01

Table G3: Darlington Nuclear – Bowmanville Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	1.23E-04	1.42E-07	1.33E-06	3.33E-11	4.12E-13	7.69E-12	1.46E-10	9.36E-12	0.00E+00	1.13E-04	5.35E-02	1.05E-02	6.42E-02
	Co-60	uSv/a	4.01E-06	1.52E-07	0.00E+00	0.00E+00	2.13E-09	2.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.09E-05	3.70E-07	2.24E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	4.94E-04	1.06E-05	5.89E-08	3.85E-03	7.13E-07	3.61E-04	0.00E+00	0.00E+00	1.10E-05	0.00E+00	4.73E-03
	HT	uSv/a	1.78E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E-06
	HTO	uSv/a	4.37E-02	0.00E+00	2.29E-02	1.71E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.62E-06	9.80E-03	1.81E-03	8.00E-02
	NobleGases	uSv/a	0.00E+00	2.62E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.62E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.94E-07	1.50E-03	1.18E-03	2.68E-03
	I (mfp)	uSv/a	4.56E-05	3.57E-06	0.00E+00	0.00E+00	2.28E-10	1.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.25E-04	7.03E-05	9.54E-04
	Total	uSv/a	4.39E-02	2.62E-02	2.34E-02	1.72E-03	6.13E-08	6.07E-03	7.13E-07	3.61E-04	0.00E+00	1.15E-04	6.57E-02	1.36E-02	1.81E-01
Child 10y	C-14	uSv/a	1.69E-04	1.36E-07	9.36E-07	3.41E-11	2.33E-12	7.89E-12	8.29E-10	9.60E-12	0.00E+00	6.83E-05	4.06E-02	6.47E-03	4.73E-02
	Co-60	uSv/a	5.55E-06	1.47E-07	0.00E+00	0.00E+00	2.57E-08	2.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.15E-05	6.41E-07	2.11E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	1.94E-04	1.09E-05	1.86E-07	3.95E-03	2.25E-06	3.71E-04	0.00E+00	0.00E+00	4.59E-06	0.00E+00	4.53E-03
	HT	uSv/a	2.06E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E-06
	HTO	uSv/a	5.05E-02	0.00E+00	1.46E-02	1.46E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.88E-07	6.73E-03	1.00E-03	7.43E-02
	NobleGases	uSv/a	0.00E+00	2.57E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.57E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.18E-07	1.18E-03	7.05E-04	1.88E-03
	I (mfp)	uSv/a	1.00E-04	3.47E-06	0.00E+00	0.00E+00	2.09E-09	9.81E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.96E-04	1.17E-04	1.23E-03
	Total	uSv/a	5.07E-02	2.57E-02	1.48E-02	1.47E-03	2.14E-07	6.02E-03	2.25E-06	3.71E-04	0.00E+00	6.96E-05	4.96E-02	8.30E-03	1.57E-01
Infant_1y	C-14	uSv/a	1.15E-04	1.36E-07	0.00E+00	5.05E-12	4.67E-12	7.89E-12	1.66E-09	9.60E-12	0.00E+00	4.02E-05	3.92E-02	5.80E-03	4.51E-02
	Co-60	uSv/a	4.07E-06	1.92E-07	0.00E+00	0.00E+00	6.30E-08	2.67E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-05	7.76E-07	2.73E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	0.00E+00	2.10E-06	2.23E-07	5.15E-03	2.70E-06	4.82E-04	0.00E+00	0.00E+00	2.24E-06	0.00E+00	5.63E-03
	HT	uSv/a	1.41E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E-06
	HTO	uSv/a	3.46E-02	0.00E+00	0.00E+00	1.59E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E-07	6.33E-03	9.81E-04	4.21E-02
	NobleGases	uSv/a	0.00E+00	3.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.15E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E-07	1.02E-03	6.89E-04	1.69E-03
	I (mfp)	uSv/a	1.17E-04	4.51E-06	0.00E+00	0.00E+00	7.33E-09	1.28E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-03	2.32E-04	1.77E-03
	Total	uSv/a	3.48E-02	3.15E-02	0.00E+00	1.61E-04	2.94E-07	7.83E-03	2.70E-06	4.82E-04	0.00E+00	4.10E-05	4.80E-02	7.68E-03	1.31E-01

Table G4: Darlington Nuclear – Industrial/Commercial Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	1.04E-04	1.20E-07	7.32E-07	8.94E-12	1.11E-13	2.06E-12	3.93E-11	2.51E-12	0.00E+00	3.03E-05	1.44E-02	2.82E-03	1.73E-02
	Co-60	uSv/a	2.98E-06	1.13E-07	0.00E+00	0.00E+00	2.31E-09	2.39E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.31E-06	9.95E-08	2.40E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	2.72E-04	2.86E-06	1.58E-08	1.03E-03	1.91E-07	9.70E-05	0.00E+00	0.00E+00	2.95E-06	0.00E+00	1.41E-03
	HT	uSv/a	1.33E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-06
	HTO	uSv/a	3.25E-02	0.00E+00	1.26E-02	4.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.34E-07	2.63E-03	4.86E-04	4.87E-02
	NobleGases	uSv/a	0.00E+00	1.69E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.69E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-07	4.03E-04	3.17E-04	7.20E-04
	I (mfp)	uSv/a	3.39E-05	2.65E-06	0.00E+00	0.00E+00	1.72E-10	7.61E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-04	1.89E-05	2.84E-04
	Total	uSv/a	3.27E-02	1.69E-02	1.29E-02	4.62E-04	1.83E-08	3.43E-03	1.91E-07	9.70E-05	0.00E+00	3.09E-05	1.76E-02	3.64E-03	8.78E-02

Table G5: Darlington Nuclear – West/East Beach Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	2.40E-04	2.76E-07	3.06E-06	5.31E-11	1.15E-13	2.15E-12	1.48E-10	9.47E-12	0.00E+00	2.21E-03	5.12E-02	5.59E-03	5.93E-02
	Co-60	uSv/a	4.82E-06	1.83E-07	8.11E-08	8.15E-09	1.87E-09	1.94E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.14E-05	2.22E-07	1.98E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	9.64E-05	4.88E-06	1.65E-08	1.08E-03	7.21E-07	3.65E-04	0.00E+00	0.00E+00	9.96E-07	2.14E-07	1.55E-03
	HT	uSv/a	2.15E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E-06
	HTO	uSv/a	5.26E-02	0.00E+00	7.27E-02	2.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.17E-05	8.72E-03	1.67E-04	1.36E-01
	NobleGases	uSv/a	0.00E+00	1.02E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-05	1.33E-03	1.04E-04	1.44E-03
	I (mfp)	uSv/a	5.49E-05	4.11E-06	8.76E-07	3.43E-09	2.73E-10	1.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.27E-04	2.99E-05	9.29E-04
	Total	uSv/a	5.29E-02	1.02E-02	7.28E-02	2.07E-03	1.86E-08	3.03E-03	7.21E-07	3.65E-04	0.00E+00	2.26E-03	6.21E-02	5.89E-03	2.12E-01
Child 10y	C-14	uSv/a	3.40E-04	2.74E-07	2.18E-06	5.39E-11	6.46E-13	2.18E-12	8.29E-10	9.60E-12	0.00E+00	1.32E-03	3.84E-02	3.35E-03	4.34E-02
	Co-60	uSv/a	6.81E-06	1.81E-07	1.37E-07	8.27E-09	2.31E-08	1.85E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.17E-05	3.28E-07	1.91E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	3.52E-05	4.94E-06	5.15E-08	1.09E-03	2.25E-06	3.71E-04	0.00E+00	0.00E+00	3.95E-07	6.58E-08	1.51E-03
	HT	uSv/a	2.52E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E-06
	HTO	uSv/a	6.19E-02	0.00E+00	4.71E-02	1.74E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-05	5.90E-03	9.30E-05	1.17E-01
	NobleGases	uSv/a	0.00E+00	9.68E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.68E-03
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.10E-06	1.02E-03	6.13E-05	1.09E-03
	I (mfp)	uSv/a	1.23E-04	4.06E-06	1.08E-06	3.48E-09	2.55E-09	1.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.88E-04	4.76E-05	1.18E-03
	Total	uSv/a	6.24E-02	9.69E-03	4.72E-02	1.75E-03	7.72E-08	2.96E-03	2.25E-06	3.71E-04	0.00E+00	1.35E-03	4.63E-02	3.56E-03	1.76E-01
Infant 1y	C-14	uSv/a	2.32E-04	2.74E-07	0.00E+00	1.53E-11	1.29E-12	2.18E-12	1.66E-09	9.60E-12	0.00E+00	7.80E-04	3.75E-02	2.67E-03	4.11E-02
	Co-60	uSv/a	4.99E-06	2.35E-07	0.00E+00	1.07E-08	5.68E-08	2.41E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.13E-05	3.83E-07	2.47E-03
	Cs-137	uSv/a	0.00E+00	0.00E+00	0.00E+00	3.38E-07	6.17E-08	1.42E-03	2.70E-06	4.82E-04	0.00E+00	0.00E+00	2.00E-07	3.31E-08	1.91E-03
	HT	uSv/a	1.73E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-06
	HTO	uSv/a	4.24E-02	0.00E+00	0.00E+00	4.36E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.07E-05	5.64E-03	1.11E-04	4.86E-02
	NobleGases	uSv/a	0.00E+00	1.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.92E-06	9.01E-04	7.18E-05	9.78E-04
	I (mfp)	uSv/a	1.44E-04	5.28E-06	0.00E+00	4.52E-09	8.92E-09	1.55E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-03	8.12E-05	1.64E-03
	Total	uSv/a	4.28E-02	1.19E-02	0.00E+00	4.36E-04	1.27E-07	3.85E-03	2.70E-06	4.82E-04	0.00E+00	7.95E-04	4.55E-02	2.93E-03	1.09E-01

Table G6: Darlington Nuclear – Rural Resident Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	Sv/a	1.39E-04	1.60E-07	1.68E-06	3.61E-11	4.00E-14	7.45E-13	1.47E-10	9.43E-12	0.00E+00	6.58E-04	4.91E-02	1.28E-02	6.27E-02
	Co-60	Sv/a	6.65E-06	2.52E-07	1.72E-07	1.32E-08	5.99E-09	6.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.44E-05	1.17E-06	6.25E-03
	Cs-137	Sv/a	0.00E+00	0.00E+00	1.09E-04	4.84E-06	5.71E-09	3.73E-04	7.18E-07	3.64E-04	0.00E+00	0.00E+00	3.33E-06	1.71E-07	8.54E-04
	HT	Sv/a	2.96E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.96E-06
	HTO	Sv/a	7.26E-02	0.00E+00	9.93E-02	2.04E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.45E-06	1.50E-02	2.26E-03	1.91E-01
	NobleGases	Sv/a	0.00E+00	4.47E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.47E-02
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.06E-06	2.36E-03	1.46E-03	3.82E-03
	I (mfp)	Sv/a	7.60E-05	6.32E-06	7.96E-07	2.40E-09	3.87E-10	1.74E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.13E-04	1.26E-04	1.14E-03
	Total	Sv/a	7.28E-02	4.47E-02	9.94E-02	2.04E-03	1.21E-08	6.60E-03	7.18E-07	3.64E-04	0.00E+00	6.72E-04	6.74E-02	1.67E-02	3.11E-01
Child 10y	C-14	Sv/a	1.94E-04	1.56E-07	1.19E-06	3.67E-11	2.25E-13	7.59E-13	8.29E-10	9.60E-12	0.00E+00	3.96E-04	3.71E-02	7.97E-03	4.56E-02
	Co-60	Sv/a	9.44E-06	2.51E-07	2.91E-07	1.34E-08	7.71E-06	6.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.69E-05	2.01E-06	6.24E-03
	Cs-137	Sv/a	0.00E+00	0.00E+00	3.91E-05	4.93E-06	1.79E-08	3.80E-04	2.25E-06	3.71E-04	0.00E+00	0.00E+00	1.38E-06	6.26E-08	7.98E-04
	HT	Sv/a	3.50E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-06
	HTO	Sv/a	8.58E-02	0.00E+00	6.47E-02	1.73E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.15E-06	1.02E-02	1.21E-03	1.64E-01
	NobleGases	Sv/a	0.00E+00	4.47E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.47E-02
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.42E-06	1.84E-03	8.42E-04	2.68E-03
	I (mfp)	Sv/a	1.71E-04	6.30E-06	9.85E-07	2.45E-09	3.64E-09	1.73E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-03	2.21E-04	1.51E-03
	Total	Sv/a	8.62E-02	4.47E-02	6.47E-02	1.74E-03	9.86E-08	6.57E-03	2.25E-06	3.71E-04	0.00E+00	4.04E-04	5.03E-02	1.02E-02	2.65E-01
Infant_1y	C-14	Sv/a	1.32E-04	1.56E-07	0.00E+00	8.80E-12	4.49E-13	7.59E-13	1.66E-09	9.60E-12	0.00E+00	2.33E-04	3.68E-02	9.26E-03	4.64E-02
	Co-60	Sv/a	6.92E-06	3.26E-07	0.00E+00	1.74E-08	1.89E-07	8.03E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E-05	3.04E-06	8.09E-03
	Cs-137	Sv/a	0.00E+00	0.00E+00	0.00E+00	3.22E-07	2.15E-08	4.95E-04	2.70E-06	4.82E-04	0.00E+00	0.00E+00	7.21E-07	3.74E-08	9.81E-04
	HT	Sv/a	2.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.40E-06
	HTO	Sv/a	5.88E-02	0.00E+00	0.00E+00	4.20E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E-06	9.08E-03	1.60E-03	6.99E-02
	NobleGases	Sv/a	0.00E+00	5.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E-02
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E-06	1.53E-03	1.07E-03	2.60E-03
	I (mfp)	Sv/a	2.00E-04	8.19E-06	0.00E+00	3.18E-09	1.27E-08	2.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-03	7.01E-04	2.45E-03
	Total	Sv/a	5.92E-02	5.48E-02	0.00E+00	4.20E-04	2.23E-07	8.54E-03	2.70E-06	4.82E-04	0.00E+00	2.38E-04	4.90E-02	1.26E-02	1.85E-01

Table G7: Darlington Nuclear – Provincial Park Camper Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	6.79E-05	7.81E-08	8.95E-07	2.50E-11	0.00E+00	0.00E+00	1.50E-10	9.60E-12	0.00E+00	6.63E-03	2.94E-02	6.64E-03	4.28E-02
	Co-60	uSv/a	3.04E-06	1.15E-07	0.00E+00	0.00E+00	2.79E-09	2.89E-03	0.00E+00	0.00E+00	0.00E+00	4.04E-07	2.07E-05	6.06E-07	2.92E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	3.33E-04	8.00E-06	0.00E+00	0.00E+00	7.31E-07	3.71E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.12E-04
	HT	uSv/a	1.35E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-06
	HTO	uSv/a	3.32E-02	0.00E+00	2.03E-02	1.59E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.42E-04	5.44E-03	1.07E-03	6.20E-02
	NobleGases	uSv/a	0.00E+00	3.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E-04	8.46E-04	6.92E-04	1.73E-03
	I (mfp)	uSv/a	3.47E-05	2.84E-06	0.00E+00	0.00E+00	1.77E-10	7.93E-06	0.00E+00	0.00E+00	0.00E+00	3.67E-07	5.40E-04	7.08E-05	6.56E-04
	Total	uSv/a	3.33E-02	3.42E-02	2.06E-02	1.60E-03	2.97E-09	2.90E-03	7.31E-07	3.71E-04	0.00E+00	7.26E-03	3.63E-02	8.48E-03	1.45E-01
Child 10y	C-14	uSv/a	9.69E-05	7.81E-08	6.35E-07	2.50E-11	0.00E+00	0.00E+00	8.29E-10	9.60E-12	0.00E+00	3.92E-03	2.17E-02	3.96E-03	2.97E-02
	Co-60	uSv/a	4.34E-06	1.15E-07	0.00E+00	0.00E+00	3.61E-08	2.89E-03	0.00E+00	0.00E+00	0.00E+00	5.60E-07	3.35E-05	9.86E-07	2.93E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	1.32E-04	8.00E-06	0.00E+00	0.00E+00	2.25E-06	3.71E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.13E-04
	HT	uSv/a	1.61E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.61E-06
	HTO	uSv/a	3.94E-02	0.00E+00	1.31E-02	1.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.36E-04	3.62E-03	5.60E-04	5.82E-02
	NobleGases	uSv/a	0.00E+00	3.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-04	6.44E-04	3.87E-04	1.14E-03
	I (mfp)	uSv/a	7.86E-05	2.84E-06	0.00E+00	0.00E+00	1.67E-09	7.93E-06	0.00E+00	0.00E+00	0.00E+00	3.71E-07	6.34E-04	1.24E-04	8.48E-04
	Total	uSv/a	3.96E-02	3.42E-02	1.32E-02	1.33E-03	3.78E-08	2.90E-03	2.25E-06	3.71E-04	0.00E+00	4.26E-03	2.66E-02	5.04E-03	1.28E-01
Infant_1y	C-14	uSv/a	6.61E-05	7.81E-08	0.00E+00	2.69E-12	0.00E+00	0.00E+00	1.66E-09	9.60E-12	0.00E+00	2.31E-03	2.01E-02	4.18E-03	2.67E-02
	Co-60	uSv/a	3.18E-06	1.50E-07	0.00E+00	0.00E+00	8.87E-08	3.76E-03	0.00E+00	0.00E+00	0.00E+00	4.05E-07	3.26E-05	1.13E-06	3.80E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	1.12E-06	0.00E+00	0.00E+00	2.70E-06	4.82E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.85E-04
	HT	uSv/a	1.10E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06
	HTO	uSv/a	2.70E-02	0.00E+00	0.00E+00	1.11E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-04	3.30E-03	7.10E-04	3.13E-02
	NobleGases	uSv/a	0.00E+00	4.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.20E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.76E-05	5.46E-04	4.79E-04	1.09E-03
	I (mfp)	uSv/a	9.19E-05	3.69E-06	0.00E+00	0.00E+00	5.86E-09	1.03E-05	0.00E+00	0.00E+00	0.00E+00	3.83E-07	8.80E-04	2.77E-04	1.26E-03
	Total	uSv/a	2.72E-02	4.20E-02	0.00E+00	1.13E-04	9.46E-08	3.77E-03	2.70E-06	4.82E-04	0.00E+00	2.52E-03	2.49E-02	5.64E-03	1.07E-01

Table G8: Darlington Nuclear – Oshawa Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	Sv/a	3.91E-05	4.49E-08	1.48E-06	3.51E-11	4.47E-13	8.32E-12	1.48E-10	9.51E-12	0.00E+00	2.13E-03	2.51E-02	3.09E-04	2.78E-02
	Co-60	Sv/a	1.27E-06	4.81E-08	0.00E+00	0.00E+00	1.20E-09	1.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E-05	5.78E-09	1.26E-03
	Cs-137+	Sv/a	0.00E+00	0.00E+00	5.56E-04	1.12E-05	6.38E-08	4.17E-03	7.25E-07	3.67E-04	0.00E+00	0.00E+00	9.02E-06	0.00E+00	5.11E-03
	HT	Sv/a	5.64E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.64E-07
	HTO	Sv/a	1.38E-02	0.00E+00	3.38E-02	1.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-05	4.94E-03	7.30E-05	5.47E-02
	NobleGases	Sv/a	0.00E+00	6.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.58E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E-05	7.64E-04	4.83E-05	8.25E-04
	I (mfp)	Sv/a	1.43E-05	9.65E-07	0.00E+00	0.00E+00	7.39E-11	3.22E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.74E-04	1.39E-07	3.92E-04
	Total	Sv/a	1.39E-02	6.58E-03	3.44E-02	1.97E-03	6.51E-08	5.42E-03	7.25E-07	3.67E-04	0.00E+00	2.18E-03	3.14E-02	4.30E-04	9.66E-02
Child 10y	C-14	Sv/a	5.20E-05	4.19E-08	1.06E-06	3.54E-11	2.49E-12	8.40E-12	8.29E-10	9.60E-12	0.00E+00	1.27E-03	1.89E-02	1.78E-04	2.08E-02
	Co-60	Sv/a	1.71E-06	4.55E-08	0.00E+00	0.00E+00	1.47E-08	1.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.35E-05	7.93E-09	1.21E-03
	Cs-137+	Sv/a	0.00E+00	0.00E+00	2.20E-04	1.13E-05	1.98E-07	4.21E-03	2.25E-06	3.71E-04	0.00E+00	0.00E+00	3.71E-06	0.00E+00	4.82E-03
	HT	Sv/a	6.35E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.35E-07
	HTO	Sv/a	1.56E-02	0.00E+00	2.18E-02	1.65E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-05	3.34E-03	3.82E-05	4.24E-02
	NobleGases	Sv/a	0.00E+00	6.23E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.23E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.78E-06	5.88E-04	2.77E-05	6.24E-04
	I (mfp)	Sv/a	3.08E-05	9.04E-07	0.00E+00	0.00E+00	6.61E-10	3.04E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-04	1.86E-07	4.80E-04
	Total	Sv/a	1.57E-02	6.23E-03	2.20E-02	1.66E-03	2.14E-07	5.39E-03	2.25E-06	3.71E-04	0.00E+00	1.30E-03	2.33E-02	3.44E-04	7.62E-02
Infant 1y	C-14	Sv/a	3.55E-05	4.19E-08	0.00E+00	5.38E-12	4.97E-12	8.40E-12	1.66E-09	9.60E-12	0.00E+00	7.49E-04	1.81E-02	2.27E-04	1.91E-02
	Co-60	Sv/a	1.26E-06	5.92E-08	0.00E+00	0.00E+00	3.62E-08	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.33E-05	1.34E-08	1.56E-03
	Cs-137+	Sv/a	0.00E+00	0.00E+00	0.00E+00	2.24E-06	2.38E-07	5.48E-03	2.70E-06	4.82E-04	0.00E+00	0.00E+00	1.79E-06	0.00E+00	5.97E-03
	HT	Sv/a	4.35E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.35E-07
	HTO	Sv/a	1.07E-02	0.00E+00	0.00E+00	2.23E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-05	3.08E-03	5.16E-05	1.38E-02
	NobleGases	Sv/a	0.00E+00	7.65E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.65E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.72E-06	5.04E-04	3.65E-05	5.45E-04
	I (mfp)	Sv/a	3.60E-05	1.17E-06	0.00E+00	0.00E+00	2.31E-09	3.96E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.27E-04	4.17E-07	6.69E-04
	Total	Sv/a	1.07E-02	7.65E-03	0.00E+00	2.25E-04	2.76E-07	7.02E-03	2.70E-06	4.82E-04	0.00E+00	7.64E-04	2.23E-02	3.16E-04	4.95E-02

Table G9: Darlington Nuclear – Fisher Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C 14	Sv/a	1.00E-04	1.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E-02	0.00E+00	0.00E+00	1.90E-02
	Co-60	Sv/a	3.30E-06	1.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-06
	Cs-137+	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	HT	Sv/a	1.47E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E-06
	HTO	Sv/a	3.72E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E-04	0.00E+00	0.00E+00	3.75E-02
	NobleGases	Sv/a	0.00E+00	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-04	0.00E+00	0.00E+00	1.17E-04
	I (mfp)	Sv/a	3.74E-05	2.48E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.99E-05
	Total	Sv/a	3.73E-02	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-02	0.00E+00	0.00E+00	5.92E-02
Child 10y	C 14	Sv/a	1.43E-04	1.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-02	0.00E+00	0.00E+00	1.13E-02
	Co-60	Sv/a	4.71E-06	1.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.83E-06
	Cs-137+	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	HT	Sv/a	1.75E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-06
	HTO	Sv/a	4.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E-04	0.00E+00	0.00E+00	4.44E-02
	NobleGases	Sv/a	0.00E+00	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.85E-05	0.00E+00	0.00E+00	6.85E-05
	I (mfp)	Sv/a	8.49E-05	2.48E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.74E-05
	Total	Sv/a	4.45E-02	2.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-02	0.00E+00	0.00E+00	5.84E-02
Infant 1y	C 14	Sv/a	9.77E-05	1.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.59E-03	0.00E+00	0.00E+00	6.69E-03
	Co-60	Sv/a	3.45E-06	1.63E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.61E-06
	Cs-137+	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	HT	Sv/a	1.20E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-06
	HTO	Sv/a	3.03E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.08E-05	0.00E+00	0.00E+00	3.04E-02
	NobleGases	Sv/a	0.00E+00	3.08E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-03
	OBT	Sv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.16E-05	0.00E+00	0.00E+00	4.16E-05
	I (mfp)	Sv/a	9.93E-05	3.23E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-04
	Total	Sv/a	3.05E-02	3.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.72E-03	0.00E+00	0.00E+00	4.03E-02

Table G10: Pickering Nuclear – Farm Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C 14	uSv/a	0.00E+00	0.00E+00	2.48E 06	4.29E 10	3.02E 13	5.64E 12	4.32E 09	2.76E 10	0.00E+00	8.16E 04	6.95E 02	3.69E 02	1.07E 01
	Co 60	uSv/a	4.77E 07	1.81E 08	4.26E 09	5.12E 10	2.19E 10	2.26E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E 06	1.43E 07	2.30E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	4.69E 04	6.96E 05	2.19E 08	1.43E 03	2.60E 06	1.32E 03	0.00E+00	1.95E 04	4.37E 05	6.57E 06	3.54E 03
	HTO	uSv/a	6.69E 02	0.00E+00	9.44E 02	1.63E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.23E 05	1.66E 02	3.25E 03	1.83E 01
	NobleGases	uSv/a	0.00E+00	4.58E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.58E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.24E 05	2.51E 03	2.05E 03	4.58E 03
	I (mfp)	uSv/a	2.93E 06	2.09E 07	2.05E 08	9.45E 11	1.47E 11	6.41E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.92E 05	1.69E 05	6.98E 05
	Total	uSv/a	6.69E 02	4.58E 02	9.49E 02	1.70E 03	2.22E 08	1.66E 03	2.61E 06	1.32E 03	0.00E+00	1.09E 03	8.87E 02	4.22E 02	3.44E 01
Child 10y	C 14	uSv/a	0.00E+00	0.00E+00	1.76E 06	4.29E 10	1.67E 12	5.64E 12	2.38E 08	2.76E 10	0.00E+00	4.82E 04	5.14E 02	2.35E 02	7.54E 02
	Co 60	uSv/a	6.81E 07	1.81E 08	7.09E 09	5.12E 10	2.83E 09	2.26E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.03E 06	2.39E 07	2.31E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	1.85E 04	6.96E 05	6.75E 08	1.43E 03	8.01E 06	1.32E 03	0.00E+00	6.44E 05	1.78E 05	2.23E 06	3.10E 03
	HTO	uSv/a	7.96E 02	0.00E+00	6.07E 02	1.36E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.80E 05	1.11E 02	1.79E 03	1.55E 01
	NobleGases	uSv/a	0.00E+00	4.58E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.58E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E 05	1.91E 03	1.22E 03	3.15E 03
	I (mfp)	uSv/a	6.65E 06	2.09E 07	2.49E 08	9.45E 11	1.39E 10	6.41E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.79E 05	2.61E 05	9.15E 05
	Total	uSv/a	7.96E 02	4.58E 02	6.09E 02	1.43E 03	7.05E 08	1.66E 03	8.03E 06	1.32E 03	0.00E+00	5.88E 04	6.45E 02	2.66E 02	2.82E 01
Infant_1y	C 14	uSv/a	0.00E+00	0.00E+00	0.00E+00	7.47E 12	3.34E 12	5.64E 12	4.77E 08	2.76E 10	0.00E+00	2.84E 04	4.61E 02	1.80E 02	6.43E 02
	Co 60	uSv/a	4.99E 07	2.35E 08	0.00E+00	6.66E 10	6.94E 09	2.94E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.88E 06	2.44E 07	2.99E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	1.58E 06	8.10E 08	1.87E 03	9.61E 06	1.71E 03	0.00E+00	2.27E 05	9.62E 06	1.04E 06	3.63E 03
	HTO	uSv/a	5.45E 02	0.00E+00	0.00E+00	3.34E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E 05	1.07E 02	1.67E 03	6.73E 02
	NobleGases	uSv/a	0.00E+00	5.60E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.60E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.99E 06	1.70E 03	1.11E 03	2.82E 03
	I (mfp)	uSv/a	7.77E 06	2.71E 07	0.00E+00	1.23E 10	4.86E 10	8.33E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.98E 05	4.30E 05	1.32E 04
	Total	uSv/a	5.45E 02	5.60E 02	0.00E+00	3.36E 04	8.85E 08	2.16E 03	9.66E 06	1.71E 03	0.00E+00	3.32E 04	5.86E 02	2.08E 02	1.94E 01

Table G11: Pickering Nuclear – Dairy Farm Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C 14	uSv/a	0.00E+00	0.00E+00	3.09E 07	4.21E 10	0.00E+00	0.00E+00	4.32E 09	2.76E 10	0.00E+00	0.00E+00	4.21E 02	8.08E 02	1.23E 01
	Co 60	uSv/a	3.86E 07	1.47E 08	0.00E+00	1.38E 10	2.11E 10	2.19E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E 06	4.59E 07	2.22E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	5.83E 05	6.84E 05	0.00E+00	0.00E+00	2.60E 06	1.32E 03	0.00E+00	0.00E+00	0.00E+00	2.74E 07	1.45E 03
	HTO	uSv/a	6.06E 02	0.00E+00	8.74E 02	1.55E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E 02	2.05E 02	1.82E 01
	NobleGases	uSv/a	0.00E+00	3.97E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.97E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E 03	6.52E 03	8.52E 03
	I (mfp)	uSv/a	2.43E 06	1.35E 07	0.00E+00	2.22E 11	1.22E 11	5.39E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.13E 05	5.66E 05	1.01E 04
	Total	uSv/a	6.06E 02	3.97E 02	8.75E 02	1.62E 03	2.24E 10	2.20E 04	2.61E 06	1.32E 03	0.00E+00	0.00E+00	5.64E 02	1.08E 01	3.55E 01
Child 10y	C 14	uSv/a	0.00E+00	0.00E+00	2.19E 07	4.21E 10	0.00E+00	0.00E+00	2.38E 08	2.76E 10	0.00E+00	0.00E+00	3.09E 02	6.99E 02	1.01E 01
	Co 60	uSv/a	5.51E 07	1.47E 08	0.00E+00	1.38E 10	2.74E 09	2.19E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E 06	1.14E 06	2.24E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	2.31E 05	6.84E 05	0.00E+00	0.00E+00	8.01E 06	1.32E 03	0.00E+00	0.00E+00	0.00E+00	8.13E 08	1.42E 03
	HTO	uSv/a	7.20E 02	0.00E+00	5.62E 02	1.29E 03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.17E 03	2.32E 02	1.61E 01
	NobleGases	uSv/a	0.00E+00	3.97E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.97E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E 03	5.69E 03	7.22E 03
	I (mfp)	uSv/a	5.54E 06	1.35E 07	0.00E+00	2.22E 11	1.16E 10	5.39E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.85E 05	1.14E 04	1.69E 04
	Total	uSv/a	7.21E 02	3.97E 02	5.62E 02	1.36E 03	2.85E 09	2.20E 04	8.03E 06	1.32E 03	0.00E+00	0.00E+00	4.07E 02	9.89E 02	3.10E 01
Infant_1y	C 14	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.77E 08	2.76E 10	0.00E+00	0.00E+00	2.33E 02	1.07E 01	1.30E 01
	Co 60	uSv/a	4.04E 07	1.90E 08	0.00E+00	1.79E 10	6.71E 09	2.85E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.26E 06	2.61E 06	2.91E 04
	Cs 137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.61E 06	1.71E 03	0.00E+00	0.00E+00	0.00E+00	7.26E 08	1.72E 03
	HTO	uSv/a	4.94E 02	0.00E+00	0.00E+00	2.50E 04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.53E 03	5.21E 02	1.08E 01
	NobleGases	uSv/a	0.00E+00	4.83E 02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.83E 02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E 03	9.48E 03	1.07E 02
	I (mfp)	uSv/a	6.48E 06	1.75E 07	0.00E+00	2.89E 11	4.05E 10	7.00E 07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.48E 05	3.99E 04	4.71E 04
	Total	uSv/a	4.94E 02	4.83E 02	0.00E+00	2.50E 04	7.12E 09	2.85E 04	9.66E 06	1.71E 03	0.00E+00	0.00E+00	3.11E 02	1.69E 01	3.00E 01

Table G12: Pickering Nuclear – Industrial/Commercial Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	6.55E-04	7.53E-07	3.62E-06	3.51E-11	2.05E-13	3.82E-12	2.66E-10	1.70E-11	0.00E+00	7.47E-07	1.34E-03	4.59E-07	2.00E-03
	Co-60	uSv/a	3.54E-06	1.34E-07	3.47E-296	1.21E-11	1.82E-10	1.89E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-07	7.05E-12	1.92E-04
	Cs-137+	uSv/a	0.00E+00	0.00E+00	6.83E-04	5.69E-06	1.49E-08	9.71E-04	1.60E-07	8.12E-05	0.00E+00	1.79E-07	2.23E-06	5.06E-11	1.74E-03
	HTO	uSv/a	4.97E-01	0.00E+00	1.21E-02	1.18E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.78E-08	7.15E-04	1.18E-07	5.10E-01
	NobleGases	uSv/a	0.00E+00	3.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.25E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E-08	1.12E-04	7.02E-08	1.12E-04
	I (mfp)	uSv/a	2.18E-05	1.55E-06	0.00E+00	1.09E-12	5.87E-12	2.61E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-06	2.36E-09	2.54E-05
	Total	uSv/a	4.98E-01	3.25E-01	1.28E-02	1.23E-04	1.51E-08	1.16E-03	1.61E-07	8.12E-05	0.00E+00	9.95E-07	2.17E-03	6.49E-07	8.39E-01

Table G13: Pickering Nuclear – Correctional Institute (C2) Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	3.28E-04	3.77E-07	1.29E-05	3.86E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E-04
	Co-60	uSv/a	2.83E-06	1.07E-07	0.00E+00	0.00E+00	1.49E-09	1.55E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	2.43E-03	6.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E-03
	HTO	uSv/a	4.41E-01	0.00E+00	4.29E-02	2.70E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-01
	NobleGases	uSv/a	0.00E+00	2.43E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	I (mfp)	uSv/a	1.80E-05	1.22E-06	0.00E+00	0.00E+00	8.95E-11	4.03E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E-05
	Total	uSv/a	4.41E-01	2.43E-01	4.53E-02	2.76E-04	1.58E-09	1.55E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.31E-01
Child-10y	C-14	uSv/a	4.68E-04	3.77E-07	9.12E-06	3.86E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.78E-04
	Co-60	uSv/a	4.04E-06	1.07E-07	0.00E+00	0.00E+00	1.93E-08	1.55E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	9.61E-04	6.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.67E-04
	HTO	uSv/a	5.24E-01	0.00E+00	2.76E-02	2.25E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E-01
	NobleGases	uSv/a	0.00E+00	2.43E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	I (mfp)	uSv/a	4.08E-05	1.22E-06	0.00E+00	0.00E+00	8.45E-10	4.03E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.61E-05
	Total	uSv/a	5.24E-01	2.43E-01	2.85E-02	2.31E-04	2.02E-08	1.55E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.97E-01

Table G14: Pickering Nuclear – Fisher Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	3.10E-04	3.56E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-02	0.00E+00	0.00E+00	1.76E-02
	Co-60	uSv/a	1.68E-06	6.37E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E-06
	Cs-137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.15E-03	0.00E+00	0.00E+00	4.15E-03
	HTO	uSv/a	2.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-03	0.00E+00	0.00E+00	2.38E-01
	NobleGases	uSv/a	0.00E+00	6.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.76E-04	0.00E+00	0.00E+00	4.76E-04
	I (mfp)	uSv/a	1.03E-05	6.77E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-05
	Total	uSv/a	2.37E-01	6.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E-02	0.00E+00	0.00E+00	3.29E-01
Child 10y	C-14	uSv/a	4.42E-04	3.56E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-02	0.00E+00	0.00E+00	1.07E-02
	Co-60	uSv/a	2.40E-06	6.37E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E-06
	Cs-137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-03	0.00E+00	0.00E+00	1.37E-03
	HTO	uSv/a	2.81E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.94E-04	0.00E+00	0.00E+00	2.82E-01
	NobleGases	uSv/a	0.00E+00	6.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-04	0.00E+00	0.00E+00	2.79E-04
	I (mfp)	uSv/a	2.35E-05	6.77E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.41E-05
	Total	uSv/a	2.82E-01	6.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-02	0.00E+00	0.00E+00	3.63E-01
Infant_1y	C-14	uSv/a	3.02E-04	3.56E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.03E-03	0.00E+00	0.00E+00	6.33E-03
	Co-60	uSv/a	1.76E-06	8.28E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-06
	Cs-137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.83E-04	0.00E+00	0.00E+00	4.83E-04
	HTO	uSv/a	1.93E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.71E-04	0.00E+00	0.00E+00	1.93E-01
	NobleGases	uSv/a	0.00E+00	8.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.48E-02
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-04	0.00E+00	0.00E+00	1.70E-04
	I (mfp)	uSv/a	2.74E-05	8.81E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.83E-05
	Total	uSv/a	1.93E-01	8.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.05E-03	0.00E+00	0.00E+00	2.85E-01

Table G15: Pickering Nuclear – Urban Resident Critical Group Doses – 2011

HumanType	Radionuclide	Unit	Air (inhalation)	Air (external)	Water (ingestion)	Water (external)	Soil (ingestion)	Soil (external)	Sediment (ingestion)	Sediment (external)	Aquatic plants	Aquatic animals	Terrestrial plants	Terrestrial animals	Total
Adult	C-14	uSv/a	6.29E-04	7.23E-07	1.09E-05	5.49E-10	3.20E-12	5.97E-11	4.16E-09	2.66E-10	0.00E+00	1.17E-05	2.09E-02	7.17E-06	2.15E-02
	Co-60	uSv/a	3.46E-06	1.31E-07	5.42E-295	1.89E-10	2.85E-09	2.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-06	1.10E-10	2.95E-03
	Cs-137+	uSv/a	0.00E+00	0.00E+00	2.03E-03	8.90E-05	2.32E-07	1.52E-02	2.51E-06	1.27E-03	0.00E+00	2.80E-06	3.48E-05	7.91E-10	1.86E-02
	HTO	uSv/a	4.68E-01	0.00E+00	3.71E-02	1.84E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.48E-07	1.12E-02	1.84E-06	5.18E-01
	NobleGases	uSv/a	0.00E+00	3.85E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.85E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E-07	1.74E-03	1.10E-06	1.75E-03
	I (mfp)	uSv/a	2.12E-05	1.67E-06	0.00E+00	1.71E-11	9.18E-11	4.08E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.77E-05	3.69E-08	5.47E-05
	Total	uSv/a	4.69E-01	3.85E-01	3.91E-02	1.93E-03	2.35E-07	1.81E-02	2.51E-06	1.27E-03	0.00E+00	1.56E-05	3.39E-02	1.01E-05	9.48E-01
Child 10y	C-14	uSv/a	7.85E-04	6.32E-07	7.64E-06	5.70E-10	1.84E-11	6.20E-11	2.38E-08	2.76E-10	0.00E+00	7.17E-06	1.60E-02	8.95E-06	1.68E-02
	Co-60	uSv/a	4.33E-06	1.15E-07	9.37E-295	1.97E-10	3.82E-08	3.06E-03	0.00E+00	0.00E+00	0.00E+00	3.24E-06	3.33E-10	3.07E-03	
	Cs-137+	uSv/a	0.00E+00	0.00E+00	7.97E-04	9.24E-05	7.43E-07	1.58E-02	8.01E-06	1.32E-03	0.00E+00	9.57E-07	1.46E-05	3.05E-10	1.80E-02
	HTO	uSv/a	4.85E-01	0.00E+00	2.37E-02	1.59E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.36E-07	7.73E-03	1.26E-06	5.18E-01
	NobleGases	uSv/a	0.00E+00	3.49E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.49E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E-07	1.38E-03	7.57E-07	1.38E-03
	I (mfp)	uSv/a	4.22E-05	1.49E-06	0.00E+00	1.78E-11	9.01E-10	4.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E-05	8.24E-08	8.17E-05
	Total	uSv/a	4.86E-01	3.49E-01	2.45E-02	1.69E-03	7.82E-07	1.88E-02	8.03E-06	1.32E-03	0.00E+00	8.74E-06	2.51E-02	1.10E-05	9.07E-01
Infant_1y	C-14	uSv/a	5.36E-04	6.32E-07	0.00E+00	3.67E-11	3.67E-11	6.20E-11	4.77E-08	2.76E-10	0.00E+00	4.22E-06	1.30E-02	1.86E-05	1.35E-02
	Co-60	uSv/a	3.18E-06	1.50E-07	0.00E+00	2.56E-10	9.38E-08	3.98E-03	0.00E+00	0.00E+00	0.00E+00	3.07E-06	8.63E-10	3.99E-03	
	Cs-137+	uSv/a	0.00E+00	0.00E+00	0.00E+00	8.00E-06	8.91E-07	2.05E-02	9.61E-06	1.71E-03	0.00E+00	3.38E-07	7.16E-06	2.17E-10	2.23E-02
	HTO	uSv/a	3.32E-01	0.00E+00	0.00E+00	3.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.60E-07	6.91E-03	1.80E-06	3.40E-01
	NobleGases	uSv/a	0.00E+00	4.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.26E-01
	OBT	uSv/a	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.19E-07	1.15E-03	9.30E-07	1.15E-03
	I (mfp)	uSv/a	4.93E-05	1.94E-06	0.00E+00	2.31E-11	3.15E-09	5.51E-06	0.00E+00	0.00E+00	0.00E+00	4.58E-05	3.06E-07	1.03E-04	
	Total	uSv/a	3.33E-01	4.26E-01	0.00E+00	3.21E-04	9.88E-07	2.45E-02	9.66E-06	1.71E-03	0.00E+00	4.94E-06	2.11E-02	2.16E-05	8.06E-01

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